Vol. 8. No. 4 December, 1951

THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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PUBLISHED QUARTERLY

By the Queensland Department of Agriculture and Stock, Brisbane

Issued by Direction of Hon. H. H. COLLINS,
Secretary for Agriculture and Stock.

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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

VOL. 8. - - NO. 4.

DECEMBER, 1951.

JASSID RESISTANCE OF THE COTTON PLANT.

By A. W. S. MAY, M.Agr.Sc., Entomologist, Science Branch, Division of Plant Industry.

SUMMARY.

Terminal injury by jassids, expressed as grades of plant reaction, can be related to the nymphal population, irrespective of variety and state of growth of the crop. This association enables a determination of varietal susceptibility based on injury symptoms. For each variety, susceptibility to jassid attack can be expressed as a plant resistance index.

The method of sampling populations and the various grades of plant reaction recognised from normality to the extreme of jassid damage are described.

A correlation between plant resistance index, an expression of oviposition injury on the plant, and mean nymphal populations for each variety tested, suggests that differential varietal reaction to jassid populations is conditioned by the breeding potential within the terminal. Plant hairiness is associated with resistance to jassid oviposition.

Hair density and the type of hairs associated with the lower surface of the midrib are discussed.

A dense cover of simple unbranched and long stellate hairs for the entire length of the midrib is essential for resistance to jassid breeding. The presence of these two types automatically confers length on the general hair cover on the major veins.

Though the plant resistance index may suffice to differentiate plant material bred for jassid resistance during years when jassid populations are high, hairiness on the lower surface of the midrib can be employed in the absence of a jassid population. Only those plants possessing a uniformly long dense hair cover for the entire length of the underside of the major veins should be selected for jassid resistance.

INTRODUCTION.

In a previous paper (May, 1950) it was stated that observations made during the early 1940's suggested that the breeding of jassid-resistant varieties was the only measure likely to be of practical value in lessening damage caused by the cotton jassid (*Empoasca maculata* Evans) in Queensland.

Complementary to a plant breeding programme to evolve suitable cotton varieties, certain entomological aspects of the problem were investigated in the Central and Upper Burnett Districts from 1941 to 1945, and the findings are presented here.

The overall picture of susceptibility to jassid attack within a field of cotton represents an average value for the reactions exhibited by the individual plants. Marked contrasts in the intensity of these reactions are noticeable between fields as well as between varieties. To determine the cause of these variations an examination of the individual plant reactions within each field was undertaken.

The varying intensity of injury shown by individual plants within varieties subject to the same level of jassid population suggested a means of gauging varietal susceptibility once it had been established that intensity of injury was directly related to the jassid population on the plant. Further, variations in the plant's attraction to the jassids, as shown by gradations in leaf curl, stressed the importance of plant characters that prevented or hindered oviposition. The role of plant hairiness in this respect was also investigated.

These two lines of investigation were undertaken concurrently to determine the best method of gauging jassid resistance under Queensland conditions. The relevant literature is discussed under section headings.

RELATIONSHIP BETWEEN JASSID POPULATIONS AND PLANT INJURY.

Methods and Criteria.

Population Sampling.

Various methods have been employed in jassid population density studies. Moerdyk (1927) and Parnell and Gutsche (1928) counted the population on five leaves of plants selected at random within each variety as a means of comparing population densities. Verma and Afzal (1940) sampled the adult populations by sweeping with a hand net and counted the total population on plants selected at random so that both adults and nymphs could be considered. Gaddum (1942) counted the population on three leaves of plants selected at random, the result being expressed as the mean number of jassids per plant. Later the data were expressed as number of jassids per unit of leaf area, the leaves being assumed to be of the same size. None of these methods fulfilled requirements under Queensland conditions. Previously (May, 1950) it was shown that *Empoasca maculata* confines its activity to the region of terminal growth, and therefore population sampling must be concentrated on this region of the plant. The sampling of adult populations by sweeping was found unsuitable for plant-to-plant comparisons, while the counting of the total population on plants chosen at random was too slow and laborious for this work, particularly when plants were growing vigorously.

Since an association between population and damage to individual plants was sought, it was desirable that counts involve the wingless stages of the pest. These are mostly confined to the leaves on which eggs are deposited and hence their numbers can be expected to give a reasonably good representation of jassid activity.

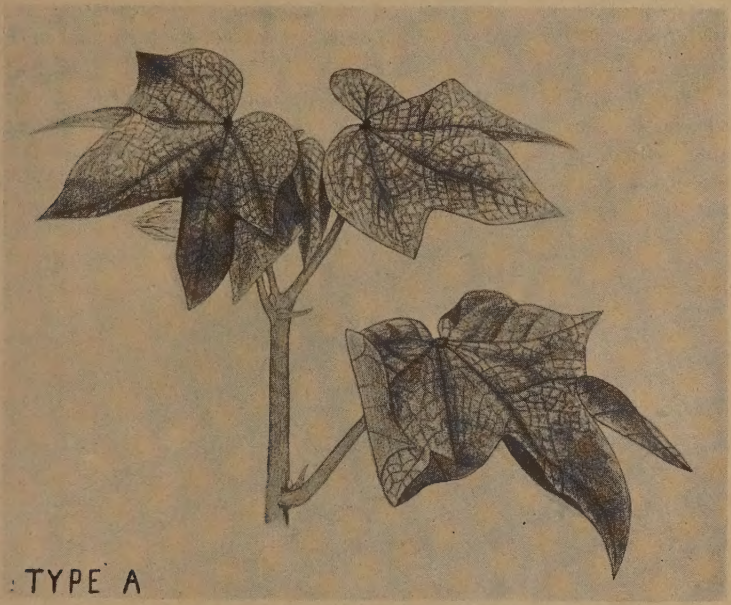

Fig. 1.
Plant Reaction Type A.

Complete counts were made of nymphal populations on the main stem terminals. Each leaf was turned back separately and carefully so that the nymphs were not unduly disturbed. In all instances, a terminal consisted of those leaves from the most recently formed down to and including the sixth. Any one series of counts was completed in the shortest time possible so that population fluctuations following variations in the growth rate of plants and the influence of adverse temperatures and storm rains were avoided.

Plant Reaction Types.

In the transition from normal growth to severe injury following jassid activity, five types of terminal injury were recognized. As this classification is somewhat arbitrary, the line of demarcation between types could not be

gauged accurately, and the allocation of marginal samples was to a certain extent subjective. This was partly overcome by sampling as many plants as possible. Types are defined as follows:—

Type A (Fig. 1).—A slight folding of the lamina may be associated with bronzing in the region of the vein tips; otherwise there is little curling or crimping of the foliage. Older leaves may show a slight curling of the leaf margins. The only symptom of injury is a discoloration of the leaf margins or of areas at the tips of the veins. Leaf colour is normal or faintly yellow.

Type B (Fig. 2).—Distinct curling is noticeable and the second and third leaves are curled downwards at the tips. The third leaf shows slight crimping, with bronzing at the margins. The third and fourth leaves exhibit chlorotic areas at the leaf margins and the extremities of main veins. There is slight drooping of the vein tips and the leaf margins only in the fifth and sixth leaves.

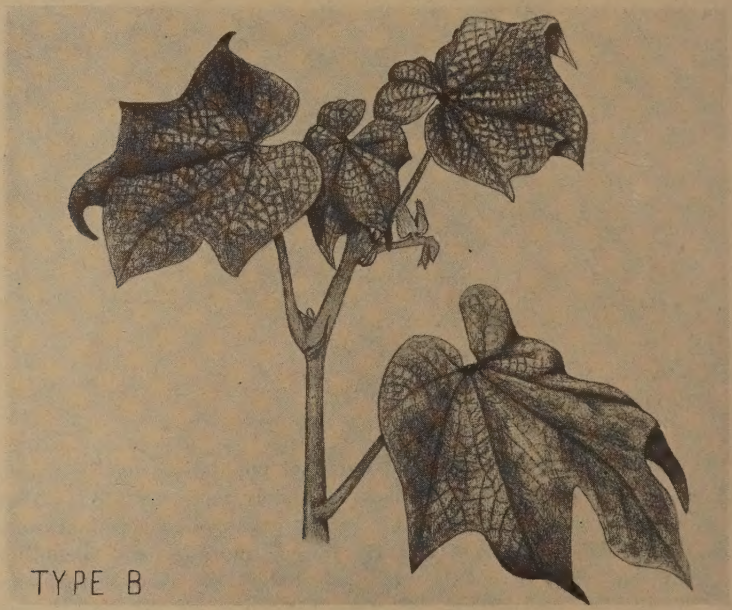

Fig. 2.
Plant Reaction Type B.

Type C (Fig. 3).—The second, third and fourth leaves show signs of curling and crimping, with the vein tips and the leaf margins curled to a moderate extent only. Slight crimping is apparent on the fifth leaf, and the sixth leaf is only slightly curled. The symptoms decrease in intensity

from the second leaf downwards and the first leaf may be devoid of injury. Slight bronzing may be evident near the vein extremities of the third, fourth and fifth leaves. The foliage is more uniformly discoloured than in Type B. Plant growth is not arrested.

Fig. 3.
Plant Reaction Type C.

Type D (Fig. 4).—All leaves show signs of curling and crimping. The vein tips and the margins of the leaves are curled under and the tissue between the main veins is severely crimped and distorted; the foliage is stiff; and the leaf petioles are reddish. Growth has been arrested and the leaves present a reddish-bronze tinge against a pale-green to yellowish background. Undeveloped squares are clustered in the growing point.

Fig. 4.
Plant Reaction Type D.

Type E (Fig. 5).—The leaves are severely curled and crimped, with the petioles short and standing at a greater angle to the main stem than usual. Undeveloped squares bunch at the growing point, or have already been shed. The leaf veins are reddish, the lamina is yellowish-green with some parts reddening, the petioles and the stems are dark-red, and the older leaves become brittle and stiff. The fourth leaf reddens at the margins and between the larger veins, and necrotic areas develop. The under-leaf surfaces are light-brown with epidermal cells conspicuous. This type is the extreme in terminal curling.

Data.

Early in the 1941-42 season, between March 12 and 21 when plant growth was reasonably good and early formed bolls had commenced to open, counts were made in three commercial varieties of cotton to determine the nymphal population associated with normal plants and the five types in the

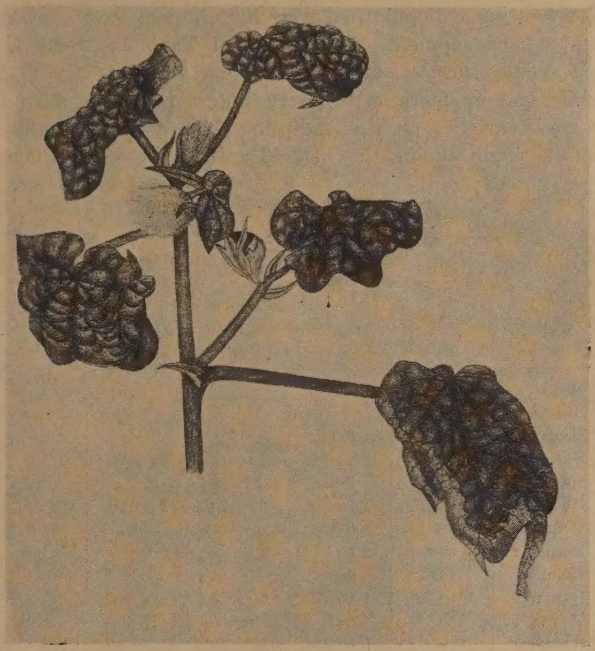

Fig. 5.
Plant Reaction Type E.

plant reaction scale. Fifty terminals were sampled for each type, but in some instances sufficient plants representative of types at either end of the scale were not available. These results are given in Table 1.

Table 1.

NYMPHAL POPULATION ASSOCIATED WITH PLANT REACTION TYPE.

Variety.	Population.	Plant Reaction Type.					
		Normal.	A	B	C	D	E
D. and P.L.	Mean ..	..	4·6	..	23·8	..	..
	Range ..	..	0 to 16	..	6 to 50	..	..
Miller ..	Mean ..	..	7·8	15·8	20·5	30·4	..
	Range ..	..	2 to 15	6 to 29	6 to 44	8 to 75	..
Half and Half	Mean ..	0·3	4·1	11·1	18·4	29·9	56·8
	Range ..	0 to 2	0 to 16	3 to 34	4 to 41	14 to 64	26 to 89

During the 1942-43 season, similar counts were made at intervals throughout late summer in a randomized varietal trial. The data collected

on March 15, when jassid populations were high, but in most cases not sufficient to suppress plant development, are set out in Table 2. Some of the plant reaction types could not be sampled in equal numbers from the material available, while one or more types were not represented among the plant samples for most varieties on this sampling date. These results are typical of similar counts made during the 1942-43 and the two subsequent seasons.

Table 2.

NYMPHAL POPULATION, MEAN AND RANGE, ASSOCIATED WITH PLANT REACTION TYPE.

Variety.	Population.	Plant Reaction Type.					
		Normal.	A	B	C	D	E
III.–509 ..	Mean ..	1·0	..	..	..	..	..
	Range ..	0 to 5	..	..	..	..	..
B_1–29–2–0	Mean ..	2·5	6·3	8·7	21·4	..	..
	Range ..	0 to 5	2 to 11	6 to 13	13 to 41	..	..
III.–26–0	Mean ..	1·1	5·5	13·7	13·7	..	..
	Range ..	0 to 5	1 to 10	8 to 20	7 to 20	..	..
B_1–9–3–0	Mean ..	1·4	6·3	11·4	9·0	24·0	..
	Range ..	0 to 4	2 to 11	4 to 22	9	24	..
Ambassador	Mean ..	1·0	4·1	10·0	..	..	..
	Range ..	0 to 6	1 to 13	6 to 14	..	..	..
Farm Relief	Mean ..	..	8·0	10·5	27·8	18·0	..
	Range ..	..	0 to 15	4 to 19	19 to 38	18	..
Miller 41 ..	Mean ..	2·5	4·3	10·2	19·8	32·3	..
	Range ..	2 to 3	3 to 7	6 to 13	7 to 41	11 to 59	..
Stoneville	Mean ..	..	6·0	10·7	16·9	43·0	..
150	Range ..	..	6	4 to 18	6 to 46	43	..
Watson ..	Mean ..	..	3·0	10·6	18·7	29·7	..
	Range ..	..	3	4 to 21	6 to 39	20 to 42	..
New Boykin	Mean ..	..	..	11·8	23·8	25·5	..
90	Range ..	..	..	8 to 17	10 to 55	16 to 38	..
Russells Big	Mean ..	..	2·0	9·0	25·7	28·5	..
Boll	Range ..	..	2	5 to 12	6 to 54	13 to 39	..
Lone Star 30	Mean ..	..	..	10·0	16·0	32·7	..
	Range ..	..	..	5 to 15	6 to 45	10 to 68	..
Qualla ..	Mean ..	..	..	7·0	17·8	41·0	..
	Range ..	..	..	5 to 9	6 to 40	27 to 55	..
Triumph	Mean ..	..	2·0	9·7	17·6	20·3	24·0
124	Range ..	..	2	7 to 12	7 to 36	5 to 39	24
New Mexico	Mean ..	..	..	..	17·1	17·3	..
Acala 120	Range ..	..	..	..	7 to 39	10 to 31	..

Discussion.

The data set out in Tables 1 and 2 demonstrate the relationship between the nymphal population on the terminal and each plant reaction type. This relationship occurs irrespective of the variety. There is a consistent increase in nymphal population for successive plant reaction types in all varieties.

Although an association between the mean nymphal population per terminal, the population range and each plant reaction type exists, the recorded values may vary at each sampling period. This is brought about by variations in the growth rate of the crop and its effect on jassid reproduction. Should the rate of plant growth remain uniform, values for the mean nymphal populations for each plant reaction type remain more or less constant. As the rate of plant growth is depressed by crop formation, adverse climatic conditions and severe jassid feeding, the chance of sampling the same terminal leaves on subsequent sampling dates increases. Although each of these leaves still exhibits much the same degree of curling, the insect population declines as some nymphs attain the more mature stages and disperse over the plants. This accounts for a gradual lowering of the mean population associated with each plant reaction type as the season progresses. With the suppression of growth, these values rapidly approach zero.

VARIETAL SUSCEPTIBILITY.

Similar injury symptoms are shown by plants subjected to equal numbers of jassid nymphs on the terminal, irrespective of variety. Thus, comparative measures of susceptibility could be arrived at simply by estimating the proportion of plant reaction types within the several varieties.

Method.

The same varieties were compared under different levels of jassid population and various climatic conditions during three subsequent seasons. The number of each plant reaction type occurring within each variety was employed as the basis of comparison. At each sampling period, determinations were completed on the one day, and for each plant sampled the injury exhibited by the main stem terminal was recorded. Where the main terminal was also injured by causes other than jassids, the plant was disregarded. Thus an equal number of plants could not be sampled for each variety.

The nymphal population associated with each terminal was also recorded.

To express more clearly the degree of curling by a variety, the data obtained on each sampling day were converted to a plant resistance index. This value was calculated by multiplying the number of terminals within each reaction type by a number from 1 to 6 representing that type, summing the products and dividing by the total number of terminals sampled. The index is given by the expression: $\frac{6n + 5a + 4b + 3c + 2d + 1e}{n + a + b + c + d + e}$, where n, a, b, c, d and e represent the number of terminals classed in plant reaction groups N (normal growth), A, B, C, D and E. The plant resistance index lies between 1 and 6, low values indicating little resistance and high values a considerable degree of resistance. Values for highly susceptible varieties will more closely approach unity during years of severe jassid activity.

Data.

Table 3 represents an example of the frequency with which the several plant reaction types occur within varieties on one sampling day. The values for each variety are an expression, at the time of sampling, of the cumulative effect of jassid activity. The mean nymphal populations associated with each plant reaction type are given in Table 2. Similar records, taken at a later date among the same plant material, showed a greater proportion of the terminals classified under the plant reaction types D and E, and with few or none towards the other end of the scale.

The varieties are listed in their order of resistance, the more susceptible being low in the scale.

Table 3.

FREQUENCY OF PLANT REACTION TYPES WITHIN VARIETIES.

Variety.	Plant Reaction Type.					
	Normal.	A	B	C	D	E
III.–509	33	..	..	..	..	..
B_1–29–2–0	14	9	6	5	..	..
III.–26–0	14	11	4	6	..	..
B_1–9–3–0	14	8	9	1	1	..
Ambassador	8	10	4	..	..	..
Farm Relief	..	8	21	4	1	..
Miller 41	2	4	5	18	3	..
Stoneville 150	..	1	13	18	1	..
Watson	..	1	10	18	4	..
New Boykin 90 ..	..	..	4	24	4	..
Russells Big Boll ..	..	1	4	20	6	..
Lone Star 30	..	..	2	25	3	..
Qualla	..	..	3	29	2	..
Triumph 124	..	1	3	19	8	1
New Mexico Acala 120..	..	..	..	22	11	..

After calculating the plant resistance index for each variety on each sampling date, Table 4 was completed.

A falling off in the growth rate, following the combined effect of crop formation and low rainfall in early April, together with decreasing temperatures, contributed towards the rapid decline in the jassid population after the end of March. During this period the more resistant varieties continued to grow and index values increased or remained almost stationary. With the more susceptible varieties, values continued to decline, although at a much reduced rate compared with that of early March, when populations were high. For some susceptible varieties, plant growth had been suppressed by the jassids by mid-March. These did not resume growth.

Table 4.

PLANT RESISTANCE INDICES.

Variety.	Plant Resistance Index.					Seasonal Mean Index.
	1.3.43.	15.3.43.	29.3.43.	19.4.43.	3.5.43.	
III.–509	6·0	6·0	6·0	5·97	6·0	5·99
B_1–29–2–0	5·81	4·94	5·06	5·35	4·97	5·23
III.–26–0	5·29	4·94	5·31	5·14	5·14	5·16
B_1–9–3–0	5·52	5·0	5·0	5·09	4·70	5·06
Ambassador	5·62	5·18	4·73	4·55	4·14	4·84
Farm Relief	4·59	4·06	3·88	4·24	3·82	4·12
Miller 41	4·67	3·50	3·33	3·45	2·85	3·56
Stoneville 150	4·53	3·42	3·36	3·21	2·21	3·35
Watson	4·45	3·24	3·15	3·06	2·36	3·25
New Boykin 90 ..	4·1	3·0	2·94	3·0	2·25	3·06
Russells Big Boll ..	4·27	3·0	3·1	2·65	2·03	3·01
Lone Star 30	4·1	2·97	2·87	2·76	2·0	2·94
Qualla	4·15	3·03	3·06	2·32	1·85	2·88
Triumph 124	3·94	2·84	2·85	2·71	1·82	2·83
New Mexico Acala 120..	3·39	2·67	2·48	2·27	1·42	2·45

Varietal susceptibility was investigated further during the 1943-44 and 1944-45 seasons, when jassid populations were lower than those recorded during the previous season. Even the more susceptible varieties showed only moderate damage. The values for the plant resistance index were high and differences between varieties were less easily established. Table 5 summarizes the findings for the three cotton seasons. All the varieties listed were not available for sampling each season.

Table 5.

RELATIONSHIP BETWEEN MEAN NYMPHAL POPULATION AND INDEX FOR VARIETIES.

Variety or Strain.	Season 1942–43.		Season 1943–44.		Season 1944–45.	
	Population.	P.R.I.	Population.	P.R.I.	Population.	P.R.I.
III.–509	·604	5·99	·009	6·0	..	..
III.–505	..	..	..	..	·27	5·96
III.–26–0–0–0	..	..	..	..	·37	5·98
B_1-29–2–0	4·11	5·23	·34	5·94	1·56	5·75
III.–26–0	4·78	5·17	·32	5·96	..	..
B_1–9–3–0	4·19	5·06	·14	6·0	·97	5·87
Ambassador	5·33	4·84	·89	5·84	3·81	5·17
Miller 41	10·45	3·56	1·89	5·61	2·85	5·35
Stoneville 150	12·27	3·35	·82	5·84	3·81	4·81
New Boykin 90 ..	13·02	3·06	3·87	5·33	7·4	4·6
Russells Big Boll ..	14·55	3·01	2·56	5·52	..	..
Lone Star 30	15·04	2·94	3·48	5·31	6·15	4·65
Triumph 124	13·22	2·83	3·42	5·42	7·17	4·7
New Mexico Acala 120..	14·72	2·45	6·44	4·81	7·85	4·46

Discussion.

Varietal differences occur in the proportions of each plant reaction type found among plants in the same field. Within each variety, plant-to-plant variation may be very marked and the summation of each plant's reaction to the existent jassid population, expressed in the plant resistance index, has enabled a comparison between varieties.

Varietal reaction to jassids is conditioned by the breeding potential within the terminal, and mean nymphal populations for varieties bear a distinct relationship to the plant resistance indices (Fig. 6).

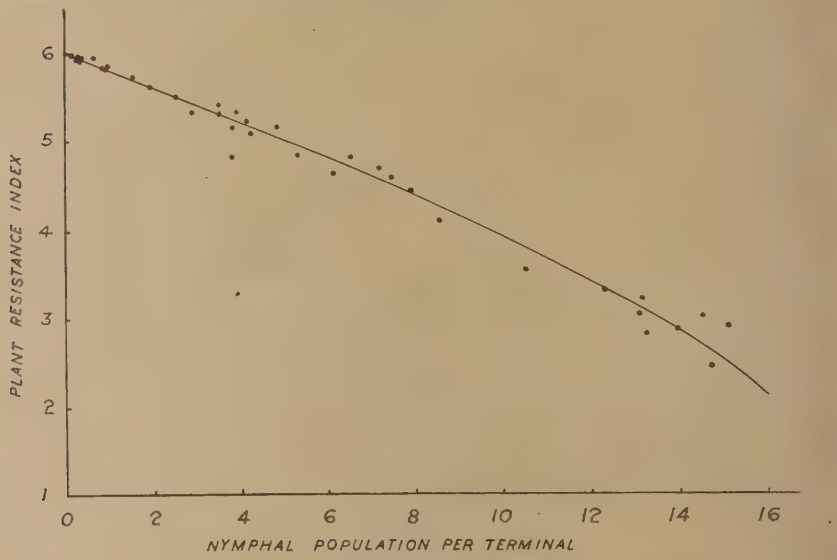

Fig. 6.

Graph Showing Relationship between Mean Jassid Population and Mean Plant Resistance Index.

The values for the plant resistance index for each variety may differ on separate counting days, although the trend remains consistent between varieties. Index values are dependent on the size of the jassid population and for any particular variety will vary considerably within a season as well as between seasons. The plant resistance indices for varieties are only comparable when recorded on the same day in crops subjected to the same jassid infestation and grown under similar cultural conditions.

Slight discrepancies in the comparative susceptibilities of the varieties studied can be understood when mean values for the nymphal populations are compared for individual seasons. The 1942-43 values of the plant resistance indices for both Triumph and New Mexico Acala are inconsistent. This

is due to the suppression of plant growth by the pest, and with it the creation of conditions unfavourable for further jassid breeding. This behaviour has prevented an absolute correlation being obtained between low index values and mean nymphal populations in Fig. 6. However, the results are sufficiently consistent to show that the more resistant varieties or strains possess characters which inhibit the development of a jassid population.

PLANT HAIRINESS.

The nymphs of cotton jassids can flourish equally well on both susceptible and resistant varieties (Peat, 1928; Husain, 1938; Verma and Afzal, 1940), yet, when resistant varieties are subject to high jassid populations, the plants remain unattractive to the pest. Though the adult jassids may cause slight feeding injury, egglaying is largely inhibited. Between varieties ranging from highly susceptible to resistant, the diversity of leaf curl exhibited has its origin in a differential rate of egg deposition, since a correlation between the mean nymphal population and the plant resistance index was found to exist. Verma and Afzal (1940) showed that the chief difference between the comparatively resistant and susceptible varieties lay in the number of eggs inserted into the leaf veins, and that these eggs, once laid, hatched normally.

Although detailed work was not undertaken at the outset to ascertain causes influencing the rate of oviposition, it was obvious that plant hairiness was associated with jassid resistance. Numerous investigators elsewhere, including Worrall (1923), Parnell (1925 and 1927), Moerdyk (1927), Afzal (1936) and Lal (1938) have reported the importance of plant hairiness in this respect. Though Parnell stressed the mechanical hindrance to jassid activity conferred by the plant hairs, certain other investigators stated that hairiness is not the basis of resistance but is correlated with some other factor. Lal suggested peculiarities within the veins which would interfere with normal oviposition, while toughness of the cuticle was stressed by Afzal and Abbas (1944).

Monteith and Hollowell (1929) and Poos and Smith (1931), working with the potato leaf hopper (*Empoasca fabae* Harris), also associated plant hairiness with resistance to insect damage.

To understand the association between plant hairiness and jassid resistance, a knowledge of hair density and type and length of hair on the plant is a primary requirement.

Methods and Criteria.

Hair Types.

According to Youngman (1930), all cotton hair types have apparently evolved from the stellate hair group. This basic type consists of a number of hairs joined together at their base and arising from a common point on the epidermis. Hector (1936) explained how simpler forms have arisen from this basic hair type, represented on the cotton plant by a short tuft-like growth

comprising six or eight rays. He stated that as the number of rays decrease, ray length increases. Simple unbranched hairs represent the extreme in this evolution.

The respective densities of the many hair types found on cotton vary considerably on different parts of the plant and also between plants. To facilitate these investigations the various hair types were grouped into three classes—(*a*) simple unbranched hairs; (*b*) long stellate forms with two or three rays; (*c*) short stellate forms with upwards of three rays per hair group.

Hair Density.

Although Parnell and MacDonald (1943) and MacDonald, Ruston and King (1944 and 1945) made use of sections or narrow strips of the petiole, midrib and leaf lamina to arrive at comparable hair density counts, others (Parnell, 1927; Peat, 1928; Afzal, 1936) counted the number of hairs within a fixed area of the surface of the leaf lamina. In all instances, the hair density was expressed as the total number of hairs, and no differentiation was made between the various hair types. Usually, a standard leaf, generally the first fully grown leaf below the growing point, was taken from each plant.

Kearney (1923) and Parnell and MacDonald (1942) were able to show that hairiness of the petiole can be correlated with that of the upper and lower leaf surfaces. Hairiness on any one of these areas presupposes that the remainder of the plant will carry a similar hair cover. Thus the hairiness of petiole, midrib or leaf lamina could be employed to present an accurate picture of plant hairiness. In these studies, the midrib was chosen as it represented the part of the plant where the greater portion of the jassid eggs are deposited. An estimate, within each variety, of the proportion of each of the three hair types on the midrib of plants provided a means of associating hair density and hair length with varietal susceptibility as expressed by the plant resistance index.

All counts were made under a binocular microscope, at x10 magnification. Only those hairs in focus along the centre of the underside of the midrib viewed from the side were considered. Values were obtained for the section between the base of the midrib and the nectary, a quarter-inch section on each side of the nectary, and a quarter-inch section approximately midway along the vein.

The choice of the leaf used for these counts was finalized after the association between hairiness and age of leaf was investigated. This involved counting the total number of hairs, irrespective of type, on each leaf in turn on the main stem of plants representing several varieties. Although some hairs were broken off the older leaves, the persistence of the hair scars enabled total counts to be obtained. The degree of leaf expansion was expressed as the measurement between the base of the midrib and the nectary.

The third leaf below the growing point was used to compare hair density between varieties. To ensure that the leaves taken at any one time were approximately of the same age, only leaves from growing terminals were sampled. Ten leaves were counted for each variety. Plant-to-plant variability was very marked within certain varieties, but the variations were rarely of sufficient magnitude to suggest that the mode of sampling would prove inadequate to express the relative varietal susceptibility.

Although no attempt was made to determine the length of the hair cover, classification into hair types provided an estimate of hair length.

Data.

Hairiness and Age of Leaf.

This association was investigated early in the 1943-44 season. Table 6 presents the total numbers of hairs counted between the base of the midrib and the nectary, together with the length of this section of the vein, for main stem leaves of plants of the same age, representing three varieties. The leaves are numbered from the growing point downwards.

Table 6.

HAIRINESS AND AGE OF LEAF.

Leaf No.	Total Hairs.					Length (sixteenths of inch).					Hairs per Unit Length (sixteenth of inch).				
	Plant No.*					Plant No.*					Plant No.*				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1 ..	25	7	35	31	29	5	5	4	3	7	5·0	1·4	8·8	10·3	4·1
2 ..	26	4	35	32	27	7	9	5	5	8	3·7	0·4	7·0	6·4	3·4
3 ..	29	4	37	30	31	10	10	6	6	10	2·9	0·4	6·1	5·0	3·1
4 ..	34	2	32	31	28	11	9	8	8	12	3·1	0·2	4·0	3·9	2·3
5 ..	28	8	35	31	24	11	11	8	10	13	2·6	0·7	4·4	3·1	1·9
6 ..	27	4	30	26	12	12	11	8	9	12	2·3	0·4	3·8	2·9	1·0
7 ..	20	5	27	26	20	13	12	8	10	11	2·0	0·4	3·4	2·6	1·8
8 ..	25	2	23	22	13	16	13	8	9	10	1·6	0·2	2·9	2·4	1·3
9 ..	20	1	23	18	9	16	11	9	8	9	1·3	0·1	2·6	2·3	1·0
10 ..	23	0	20	21	4	16	8	7	9	8	1·5	0	2·9	2·3	0·5
11 ..	23	0	†	19	11	14	9	†	7	7	1·6	0	†	2·7	1·6
12 ..	22	0	†	12	10	12	8	†	6	10	1·8	0	†	2·0	1·0
13 ..	9	..	†	17	..	10	..	†	6	..	0·9	..	†	2·8	..

* No. 1 = Labh Singh's Selection—4F Hirsutum; No. 2 = Triumph 124; Nos. 3, 4, and 5 = III–26–0–0–0.

† Leaves shed from plant.

The earliest formed leaves on these plants were produced when soil moisture and soil nutrients were adequate. Leaf area progressively increased until unfavourable growing conditions and the influence of crop formation retarded plant development. This slowing down in the growth rate is evident with leaf No. 8 in Table 6.

During the early stages of growth, hairiness increased as new leaves were formed, but this increase was not maintained on leaves formed after the crop had developed. The variation in hair cover on successive leaves is a function of plant growth and was recognized by Afzal (1936) and MacDonald, Ruston and King (1946).

Although the number of hairs may increase as new leaves are formed, hair density is a factor related to the growing conditions ruling at the time of leaf expansion. This effect was seen when hairiness was expressed as density per unit of midrib length in Table 6. Hair density remained more or less uniform, as continued leaf expansion offset the increase in hair numbers up to a point corresponding with leaf 8 on these plants. Above this, reduced leaf measurements caused a continuous increase in hair density.

The rate of increase in the number of hairs per leaf as new leaves are formed is not of sufficient magnitude to influence greatly the plant's ability to withstand jassid infestation, though low values for the early formed leaves may influence susceptibility should populations be high at the time these leaves are formed. Such conditions are sometimes satisfied in late planted crops.

Hairiness on Various Sections of Midrib.

In a series of hair counts made during the 1944-45 season, the association of hair types and hair density showed considerable variation on different sections of the midrib. This variation can be seen in the data set out in Table 7.

Table 7.

MEAN DENSITY OF HAIR TYPES ON DIFFERENT SECTIONS OF THE MIDRIB.

Variety.	Base to Nectary.			¼" Section below Nectary.			¼" Section beyond Nectary.			¼" Section at Midpoint of Vein.		
	Hair Type.*			Hair Type.			Hair Type.			Hair Type.		
	1	2	3	1	2	3	1	2	3	1	2	3
III.–26–0–0–0 ..	17·5	8·8	6·7	10·7	1·7	·5	11·3	2	2·7	10·8	2·5	4·3
III.–505	13·2	5·3	·3	9·0	1·1	·1	9·0	3·0	·3	9·1	4·1	·2
B_1–29–2–0	12·5	7·3	1·1	7·4	1·3	·6	6·3	2·9	1·1	4·6	2·8	2·2
B_1–9–3–0	7·8	8·2	·4	4·5	1·7	·3	5·6	1·9	1·2	4·8	2·7	2·1
Ambassador	5·2	4·8	·5	2·7	1·5	·3	3·5	2·8	1·3	1·5	2·3	2·3
Miller 41	8·3	3·2	·3	3·6	·3	·2	2·8	1·3	1·1	2·8	2·9	·9
Stoneville 150 ..	8·3	2·6	·8	2·8	·2	·5	1·4	·7	2·3	2·2	·7	2·9
New Boykin 90 ..	4·8	3·1	·5	1·4	·1	·3	1·1	·6	1·7	1·1	1·2	3·2
Lone Star 30 ..	4·8	2·2	·7	1·0	·2	·2	1·3	·2	1·6	1·7	1·6	1·8
Triumph 124 ..	1·1	·1	·9	·2	..	·3	·4	..	1·2	·4	·3	1·4
New Mexico Acala 120	·9	·1	·4	..	..	·4	·7	..	·7	1·8	·1	·8

* Hair types: 1 = simple unbranched hairs; 2 = long stellate hairs; 3 = short stellate hairs.

The general picture outlined above was confirmed by further hair counts made during the same season. However, the individual values differed for the same varieties, as both plant growth and time of leaf sampling varied.

A clearer picture of the variation in hair density on the midrib for varieties can be gained from the diagrams in Figs. 7-10. These diagrams also serve to show how density may differ within varieties.

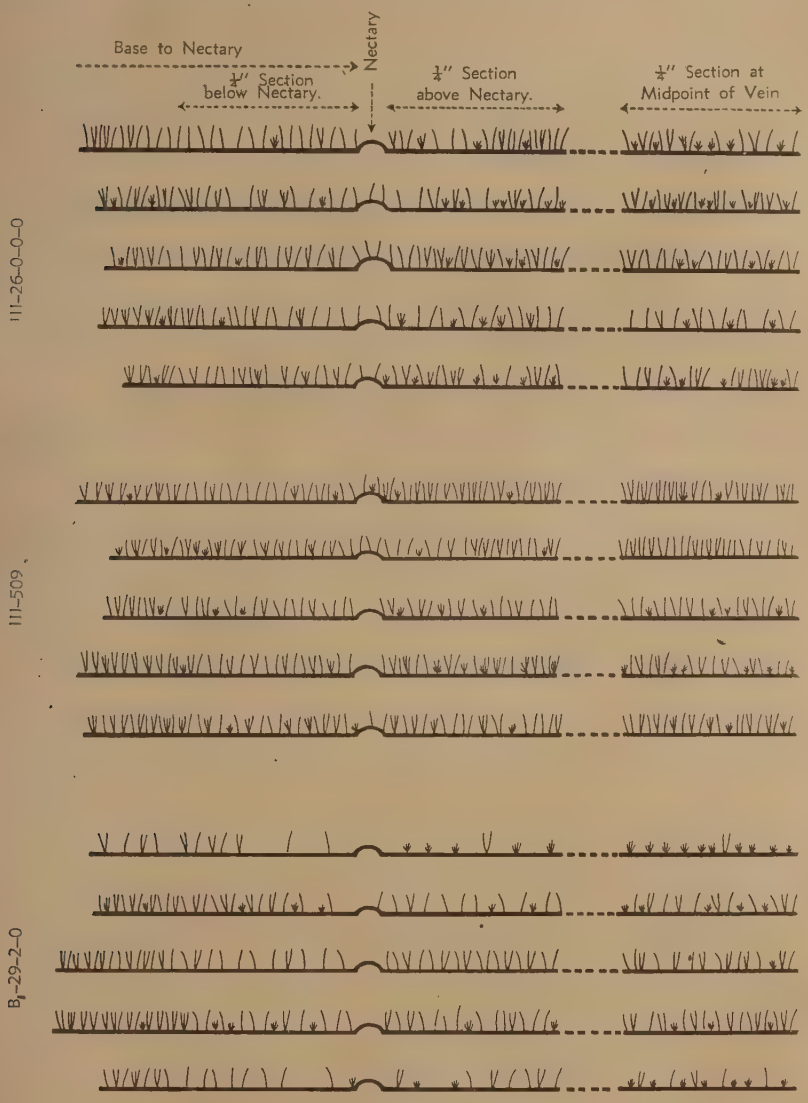

Fig. 7.
Distribution of Hair Types on the Lower Surface of the Midrib.
Varieties III-26-0-0-0; III-509; and B_1-29-2-0.

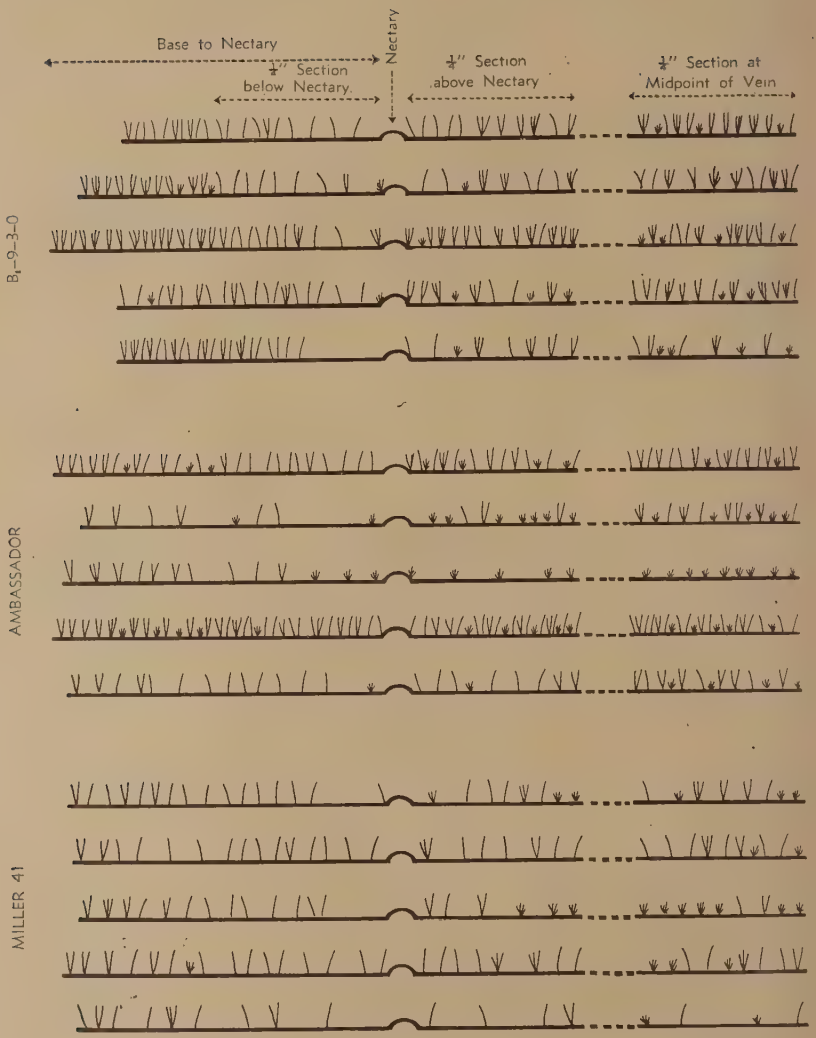

Fig. 8.

Distribution of Hair Types on the Lower Surface of the Midrib. Varieties B_1-9-3-0; Ambassador; and Miller 41.

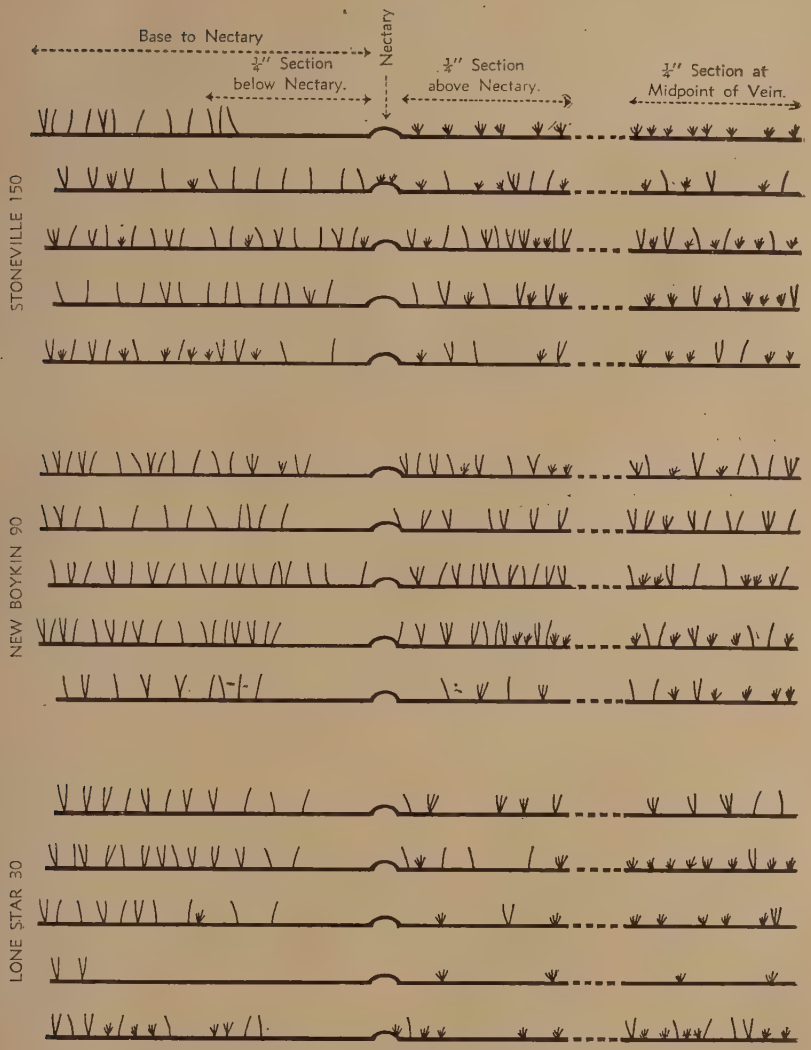

Fig. 9.

Distribution of Hair Types on the Lower Surface of the Midrib. Varieties Stoneville 150; New Boykin 90; and Lone Star 30.

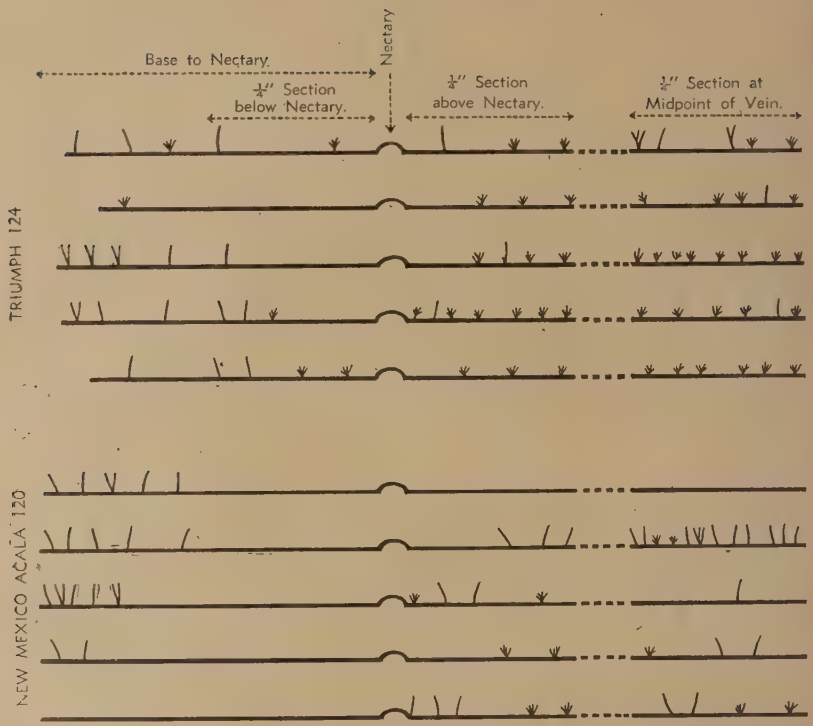

Fig. 10.

Distribution of Hair Types on the Lower Surface of the Midrib.
Varieties Triumph 124 and New Mexico Acala 120.

Table 8.

HAIR DENSITY ON DIFFERENT SECTIONS OF THE MIDRIB (PER $\frac{1}{16}$ IN.).

Variety.	Base to Point ¼" from Nectary.	¼" Section below Nectary.	¼" Section above Nectary.	¼" Section at Midpoint of Vein.
III.–26–0–0–0	5·03	3·23	4·0	4·4
III.–505	4·1	2·55	3·08	3·35
B_1–29–2–0	2·37	2·33	2·58	2·4
B_1–9–3–0	2·25	1·63	2·18	2·4
Ambassador	1·15	1·13	1·9	1·53
Miller 41	1·51	1·03	1·3	1·65
Stoneville 150	1·49	·88	1·1	1·45
New Boykin 90	1·08	·45	·85	1·38
Lone Star 30	1·26	·35	·78	1·28
Triumph 124	·34	·13	·4	·53
New Mexico Acala 120 ..	·02	·1	·35	·68

In all varieties examined, it was generally found that hairiness extended from the petiole on to the lower surface of the midrib to a degree dependent on the hairiness of the variety under examination. This extension from the petiole was evidenced by the association of hair types and their relative densities. Simple unbranched and long stellate hairs predominate on both this region of the midrib and the petiole.

Of the various sections of the midrib sampled, the quarter-inch section on the basal side of the nectary supported the least number of hairs. Table 8 also shows this, values being expressed as hairs per sixteenth of an inch.

Beyond the nectary, towards the tip of the vein, both hair density and the proportion of the three hair types considered were quite unrelated to that found on the basal portion of the midrib. The density of the simple unbranched hairs was more or less the same for each quarter-inch section sampled, though long stellate and short stellate hairs became more numerous with decreasing vein diameter.

Table 9.

CORRELATION BETWEEN HAIR TYPE AND JASSID RESISTANCE.

Variety.	Hairs on ¼" Section below Nectary. Hair Type.*			Total Hair Types 1 and 2.	Total all Types.	Plant Resistance Index.	
	1	2	3				
III.–26–0–0–0	10·7	1·7	·5	12·4	12·9	..	Highly Resistant
III.–505	9·0	1·1	·1	10·1	10·2	..	ditto
B_1–29–2–0	7·4	1·3	·6	8·7	9·3	5·23	Moderately Resistant
B_1–9–3–0	4·5	1·7	·3	6·2	6·5	5·06	ditto
Ambassador	2·7	1·5	·3	4·2	4·5	4·84	Slight Resistance
Miller 41	3·6	·3	·2	3·9	4·1	3·56	ditto
Stoneville 150	2·8	·2	·5	3·0	3·5	3·35	ditto
New Boykin 90	1·4	·1	·3	1·5	1·8	3·06	Moderately Susceptible
Lone Star 30	1·0	·2	·2	1·2	1·4	2·94	ditto
Triumph 124	·2	..	·3	·2	·5	2·83	ditto
New Mexico Acala 120	..	..	·4	..	·4	2·45	Very Susceptible

* Hair types: 1 = simple unbranched hairs; 2 = long stellate hairs; 3 = short stellate hairs.

Hairiness and Jassid Resistance.

In Table 7, the varieties are listed in the order of decreasing hair density, an arrangement that corresponds closely with decreasing jassid resistance, expressed as plant resistance indices. This correlation between the total number of hairs and the plant resistance index can also be obtained if hair density is expressed as the total of simple unbranched and long stellate hair types (Table 9).

The values for plant hairiness were compiled from data collected during the 1944-45 cotton season, when jassid populations were only moderately high. The values for plant resistance indices were calculated from the results obtained during the 1942-43 cotton season, when jassid populations were high and the number of plant reaction types within varieties enabled a more accurate estimate of jassid resistance to be made. The strains III-26-0-0-0 and III-505 were not available during the 1942-43 season, but the former proved almost completely immune to jassids during the moderate jassid attack of the 1944-45 season and was given a mean plant resistance index of 5·98. The strain III-505 is closely allied to strain III-509, which was assigned a mean plant resistance index of 5·99 during the 1942-43 season.

In the region of the nectary, hairiness increased with resistance. Resistant plants possessed a uniformly long dense cover for the entire length of the vein. Highly susceptible plants, on the other hand, were almost devoid of hairs for the greater length of the midrib but possessed a few long hairs towards the base and scattered hairs beyond the nectary towards the vein tip. These latter hairs were largely of the short stellate type. As plant hairiness and therefore jassid resistance increased, the extension of hairiness from the petiole became more pronounced. At the same time hairiness between the nectary and the vein tip intensified. In all cases this increased hairiness was due to a greater density of the longer hair types (Table 7).

Though plant hairiness tended towards a distinctive pattern for each variety, plant-to-plant variability within varieties was noticeable (Figs. 7-10). This variability depended largely on the purity of the plant material under examination. Pure strains of high jassid resistance, such as III-509 and III-26-0-0-0, showed little variation in hair density provided the plants compared were growing under similar conditions. Among commercial varieties, variation was more marked, particularly in those possessing a moderate resistance to jassid attack. Here resistant and highly susceptible plants were encountered in the same stand. The strain III-26-0-0-0 has been derived from a selection of resistant plants among a stand of the commercial variety Miller.

Discussion.

The association between hair density and susceptibility to jassid attack was repeatedly established throughout the course of these investigations. Though it has been suggested that genetically linked characters may be

responsible for this apparent association (Afzal and Abbas, 1944), the findings presented in this paper discount this possibility and point to a direct relationship between hairiness and jassid resistance.

Even when resistant plants are grown in areas subject to high jassid populations, nymphs are rarely found on the plants, though considerable adult feeding injury may develop. Such injury is invariably near the distal portion of the veins where the hair cover is much shorter. Elsewhere on the veins, feeding and oviposition by the jassids are prevented. Lal and Husain (1945) stressed the association between lack of oviposition sites and resistance rather than the inability of the insect to feed on hairy leaves.

While some plants may appear hairy, the midrib is relatively bare in the region of the nectary. Oviposition may occur on such plants when pest populations are high in the vicinity. Classification of plants into grades of jassid resistance is possible by visual observation, using the criterion hair density on the quarter-inch section of the midrib immediately below the nectary. A rough classification of varieties into broad groups can be undertaken by this method, though differentiation within groups is not possible.

Although a dense hair covering for the entire length of the vein is necessary for jassid resistance, the length of this covering is equally important. Parnell, King and Ruston (1949), investigating jassid resistance and hairiness of the cotton plant in South Africa, came to the same conclusion. The prevalence of the simple unbranched, and to a less extent the long stellate, hairs governs the length of the hair cover on the leaf veins. The numbers of these types increase directly with resistance. The former type occurs more uniformly over the length of the midrib and would thus be directly associated with resistance to attack. The short stellate hairs play little part in conferring resistance, their numbers in the general hair cover remaining fairly uniform between varieties, and may predominate on the more susceptible varieties, New Mexico Acala, Lone Star and Triumph.

APPLICATION OF RESULTS.

The plant resistance index can be employed by the plant breeder to differentiate material only under appreciable levels of jassid population. Varieties or strains evolved for jassid resistance may be rogued under this visual method of estimating susceptibility but differentiation becomes difficult among material exhibiting a measure of resistance to the pest. Such material can be separated only in years of high jassid populations.

A more reliable method of differentiating material evolved for resistance to jassid attack can be based on an estimation of plant hairiness. This can be undertaken in the field and involves the selection of those plants exhibiting a uniformly long dense hair cover for the entire length of the major veins.

Although hairy plants may exhibit a dense hair covering on the leaves, petioles and stems, midrib hairiness is the safest guide to jassid resistance.

Where a dense, long hair cover is found on the midrib, hairiness on the remainder of the plant is invariably assured. A further check on the potential resistance of a plant is obtained if it is established that the circumference of the midrib below the nectary is clothed with a long dense hair cover. The setting of a high standard for both density and length of hairs on the midrib will ensure that all material selected will possess a high measure of resistance to attack at all levels of jassid population as well as over a wide range of growing conditions.

ACKNOWLEDGMENTS.

This work could not have been attempted without the co-operation of the many farmers throughout the Central and Upper Burnett districts on whose farms observations were carried out. All experiment plots were located on Mr. A. Tomlin's property at Gayndah. Mr. S. Marriott, at the time Plant Breeder at Biloela Regional Experiment Station, and several other Departmental officers contributed to these studies. All this assistance is gratefully acknowledged.

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APPENDIX.

THE INFLUENCE OF PLANT HAIRINESS ON OTHER COTTON PESTS.

During these investigations the effect of plant hairiness on the activity of other cotton pests was observed. Generally speaking, the presence of a dense clothing of hairs on the leaf lamina is a definite hindrance to insect mobility. Mirids and other small active insects do not behave normally on such plants. There is no evidence to show that the incidence of the larger cotton bugs and lepidopterous larvae is unduly affected by plant hairiness.

It has been suggested that the cotton aphis (*Aphis gossypii* Glov.) breeds more freely on hairy plants. At no time were aphids a major problem in plots, although they were commonly located on the plants. Aphis populations were relatively high in a varietal trial during the 1942-43 season and the population density within each variety was estimated. Three fully developed leaves were selected at random from each of five plants in each of three plots, making a total of 45 leaves for each variety. The aphis infestation was classed into four grades:—(1) no aphids per leaf; (2) 0-20 aphids per leaf; (3) 20-50 aphids per leaf; and (4) over 50 aphids per leaf. The results obtained from this classification were:—

Variety.	Number of Leaves in each Grade.			
	Grade 1.	Grade 2.	Grade 3.	Grade 4.
New Mexico Acala 120	43	2	..	..
New Boykin	42	3	..	..
Miller	38	7	..	..
B_1–29–2–0	22	23	..	..
B_1–9–3–0	22	21	2	..
Stoneville	21	16	5	3
III.–26–0	15	28	2	..
III.–509	13	23	5	4

These figures suggest that conditions in jassid resistant varieties or strains favour aphis infestation. This phenomenon can scarcely be attributed to conditions within the plant and more likely is associated with the plant hairs.

Once aphids are established on the leaf, plant hairs would not greatly inconvenience their survival. However, these hairs would restrict the movement of aphis parasites and predators and may act as a deterrent to these latter insects.

Onion thrips (*Thrips tabaci* Lind.) were also found quite commonly on hirsute plants, their small size enabling them to move quite freely on the surface of the leaf. A dense hair covering would afford a certain measure of protection to this insect. However, high thrips populations were never recorded on hairy plants.

THE PREVENTION OF BORER ATTACKS ON HOOP PINE LOGS.

By A. R. BRIMBLECOMBE, M.Sc., Entomologist, Science Branch, Division of Plant Industry.

SUMMARY.

Five species of Platypodidae and two species of Scolytidae were responsible for damage to felled hoop pine logs confined to the rain-forest in the Killarney district during periods of wet weather. Platypus froggatti, the largest and most destructive species, is host specific and dominates attacks on logs near cut-over areas. The other species are polyphagous and the smaller ones dominate in virgin areas. All are strongly and positively chemotropic and attacks become intensified in a few days after or during rain. The adults commence and continue the tunnel systems which are mostly across the grain and can extend deeply into the logs.

Replicated log protection experiments were conducted, mostly with K55 standard creosote, on a total of 127 logs involving 44,563 super. feet of timber. All non-creosote treatments reduced the intensity of borer attacks but were significantly inferior to creosote. Materials mixed with creosote did not add to its value. Creosote at the rate of one gallon to 140 square feet of log surface gave virtually complete protection for 10 weeks.

INTRODUCTION.

In Queensland rain-forests serious damage by shothole and pinhole borers may be experienced when logs are not quickly transported from foci of borer infestation to local mills or railheads. Increased attention to tracks and roads in the forest and the construction of all-weather access roads have helped considerably in reducing the risk of borer attacks, and co-ordination between cutters and haulers hastens the removal of the logs soon after felling.

In some districts, however, weather, topographic and other local factors do not readily permit the quick transference of logs from the forest. Borer attacks then prevent the full economic utilization of the timber. This was the problem with hoop pine (*Araucaria cunninghamii* Ait.) logs in the Killarney district some years ago, and an investigation of chemical means of log protection was commenced in 1939 and continued for several years.

REVIEW OF LITERATURE ON LOG PROTECTION.

Few detailed investigations into the protection of logs from shothole and pinhole borers have been reported. The earliest authoritative account was by Craighead (1922) in America, and Smith (1935) later discussed non-chemical means for a specific problem in North Queensland. Since the present

investigation was commenced, Christian (1939) in America has given results obtained with many chemicals, mostly of organic origin. Hogan (1944) dealt with the protection of fire damaged timber in Victoria but did not give details of chemical treatments. Ambrosia beetles were included in an account of log treatments carried out by Holmes (194-) in Ceylon. More recently, experiments have been conducted by Browne (1949) in Malaya, by Kinghorn and Webb (1950) in Canada, and by Taylor and Hadlington (1950) and Hadlington (1951) in Australia.

In addition to the above several workers in America (Whittens, 1942; Wallace, 1943; Becker, 1946; and Connola, Collins and Hagman, 1947) have conducted experiments on various Scolytid bark beetles which are relevant to a discussion on log protection.

THE ECONOMIC IMPORTANCE OF BORER DAMAGE.

The ramifying tunnels of shothole and pinhole borers do not result in mass tissue destruction and unless numerous do not always affect the structural

A B

Fig. 1.

A, *Platypus froggatti* Samps. ♂ (× 11); B, *Platypus australis* Chap. ♂ (× 13);

[*Drawings by William Manley.*

strength of the wood. However, the appearance of borer holes on hoop pine logs almost invariably causes degrading, and in extreme instances may reduce ply logs to case timber quality. In addition to decreasing the limited number of logs available for plywood manufacture, there is considerable monetary loss in value of the logs themselves and the timber cut from them. The importance of the damage is accentuated by the fact that the natural resources of this excellent timber are quickly approaching exhaustion. Consequently, the prevention of loss by borers is of considerable importance not only in reducing the monetary loss but also in making the greatest possible use of the remaining limited supplies.

BORER SPECIES IMPLICATED.

Many insects may be associated with felled hoop pine logs and a complete study would no doubt show a succession of attacks. However, recognition is here given to seven species damaging logs in the forest during the first few months after felling. These are *Platypus froggatti* Samps., *Platypus australis*

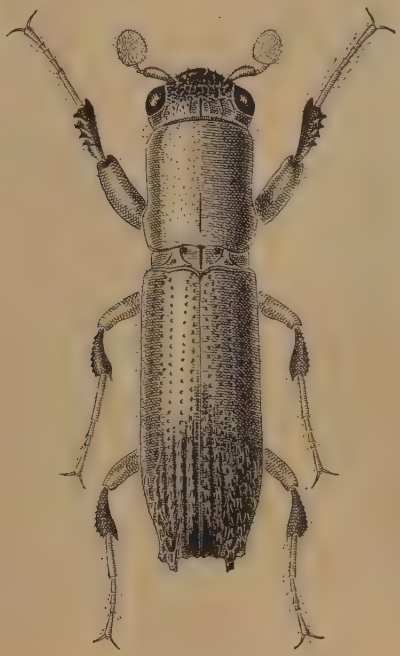


Fig. 2.

Crossotarsus omnivorus Lea ♂ (× 19).

[*Drawing by William Manley.*

Chap., *Crossotarsus omnivorus* Lea, *Platypus semigranosus* Samps. and *Platypus subgranosus* Schedl (family Platypodidae); and *Xyleborus perforans* Woll. and *Xyleborus eucalypticus* Schedl (family Scolytidae).

The presence of *P. subgranosus* in addition to *P. semigranosus* and of two separate species of *Xyleborus* was not established until after the field observations had been completed. Consequently the two species in each case are combined in subsequent discussions.

Adults of the five Platypodid species have the same general elongate shape and brown colour. Both males and females are more or less cylindrical, but each species exhibits sexual dimorphism. The difference is barely noticeable

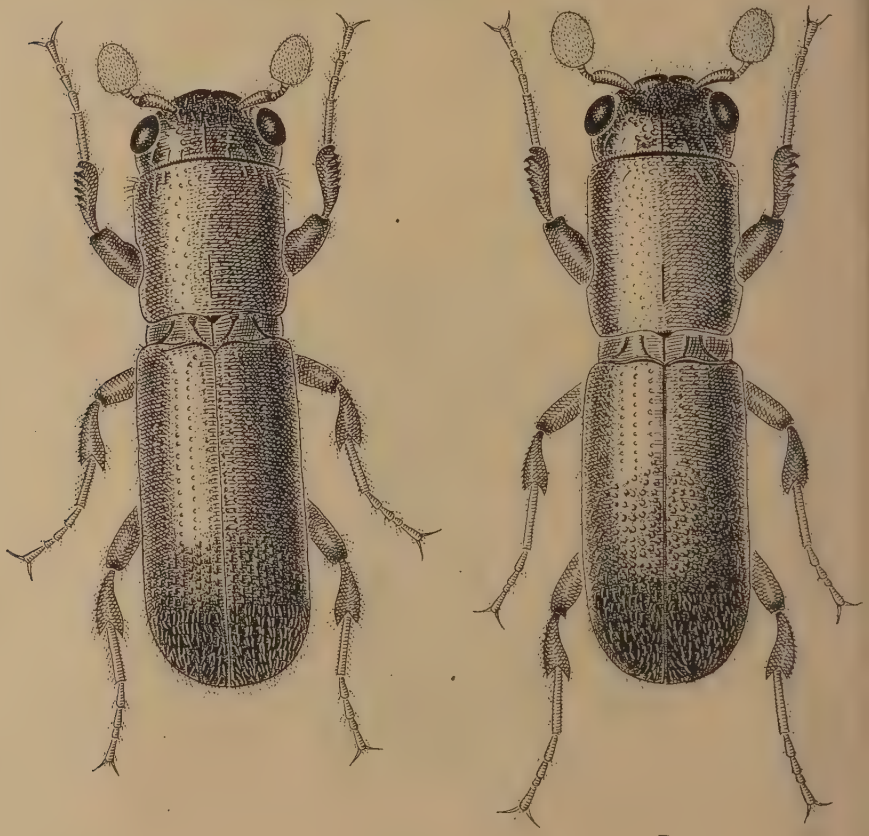
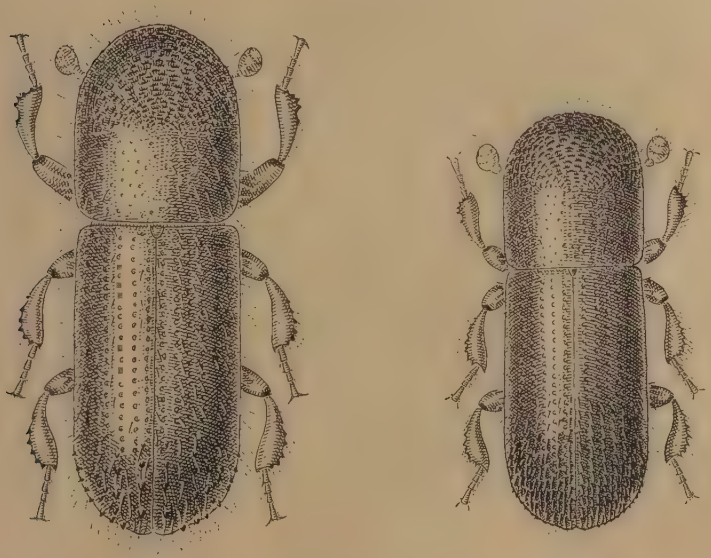


Fig. 3.

A, *Platypus subgranosus* Schedl. ♂ (× 25); B, *Platypus semigranosus* Samps. ♂ (× 25); [*Drawings by William Manley.*

in *P. froggatti* (Figure 1, A), the male being distinguished by a small blunt terminal process on each elytron. In *P. australis* (Figure 1, B) the elytra of the male are constricted appreciably to a pronounced apical declivity. In the male *C. omnivorus* (Figure 2) there is slight constriction of the elytra; each terminates in a spine and is without the pronounced apical declivity. *P. semigranosus* and *P. subgranosus* (Figure 3, B and A) are similar except that in the latter the apical third of the elytra is granose while the former has the apical half coarsely granose. The females of all species are separated, apart from size differences, only on slight differences in apical elytral characters. Measurements of length and width of each species are as follows:—

Species.		Length. mm.	Width. mm.
P. froggatti ..	♂ and ♀	6·75–7·0 ..	1·9–2·1
P. australis	♂	5·0 –5·5 ..	1·2–1·4
	♀	5·25–5·75 ..	1·3–1·5
C. omnivorus	♂	3·75–4·0 ..	1·0–1·25
	♀	4·0 –4·25 ..	1·0–1·2
P. semigranosus ..	♂	3·5 –3·75 ..	1·0–1·2
	♀	3·75–4·0 ..	1·0
P. subgranosus ..	♂	3·5 –3·75 ..	1·0–1·2
	♀	3·75–4·0 ..	1·0



A B

Fig. 4.

A, *Xyleborus perforans* Woll. (× 32); B, *Xyleborus eucalypticus* Schedl (× 35).

[*Drawings by William Manley.*

The two species of *Xyleborus* (Figure 4, A and B) have the same cylindrical shape and brown colour. Macroscopically the only difference is in size and even that may be unreliable. The sexes are not readily distinguished. Measurements of length and width of each species are as follows:—

Species.	Mean Length. mm.	Mean Width. mm.
X. perforans	2·4 ..	0·8
X. eucalypticus	1·8 ..	0·65

HABITS OF THE BORERS.

Adults of the several species may be free living in the forest during moist humid weather, and are active on the wing during the daytime. All are strongly and positively chemotropic and under suitable conditions are attracted to logs on the day of felling, though normally a few days elapse before attacks become concentrated.

All species except *P. froggatti* are polyphagous and can readily penetrate the bark of most hosts. *P. froggatti* is restricted to hoop pine and enters only exposed wood. However, on barked hoop pine logs each species can commence boring in any position (Figure 5), though preference is shown for surface depressions, cracks, and the angle between wood and adhering bark fragments (Figure 6). Most species can penetrate to a depth greater than their own length in 24 hours.

In all species the adults initiate and continue boring the tunnel system. The Platypodids tunnel mostly across the grain. Entrance is normally perpendicular to the log surface but later the tunnels may change in direction and also become branched. Hoop pine sapwood is several inches thick (Figure 7), allowing scope for extensive tunnel exploitation in this tissue alone, but beetles can penetrate deeper into the log (Figure 8, B). Tunnels of *P. froggatti* have been traced across the grain for 15 inches from the surface, and along the grain for 37 inches.

The Xyleborid tunnels are also mostly across the grain but tend to be more devious and branched than those of the Platypodids. While change in direction is common a few inches from the surface, they also can penetrate well into the log.

Tunnels of both Platypodids and Xyleborids are accompanied by borer "dust," consisting of fine shreds of chewed-off wood. This is pushed back along the tunnel and eventually to the exterior so as to provide unimpeded movement by the beetles and their progeny throughout the tunnel system. With each species except *P. froggatti* the material is slightly compressed and projects as a "thread" from the entrance, sometimes for more than an inch, before falling to the ground (Figure 5 and Figure 6, A). With *P. froggatti* the dust often falls without forming a thread. Because of the greater

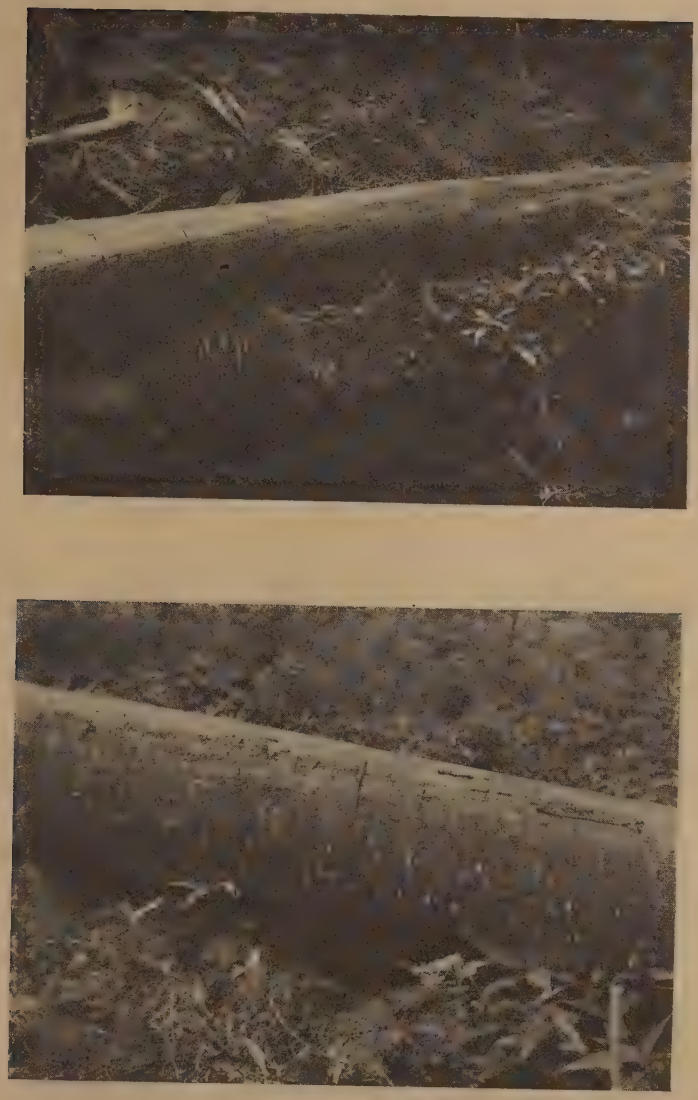
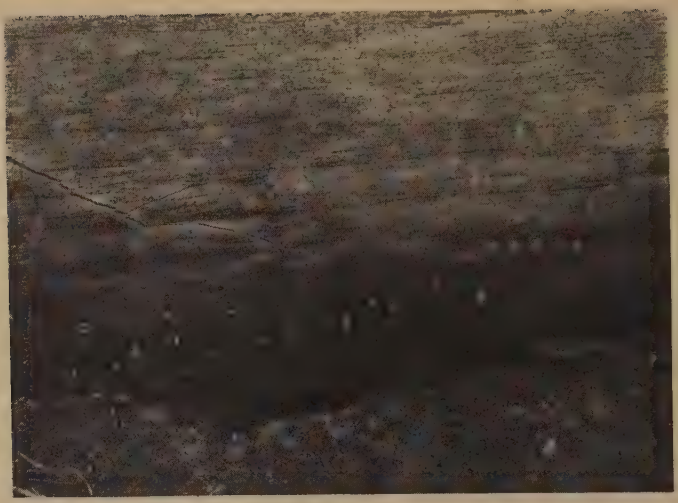
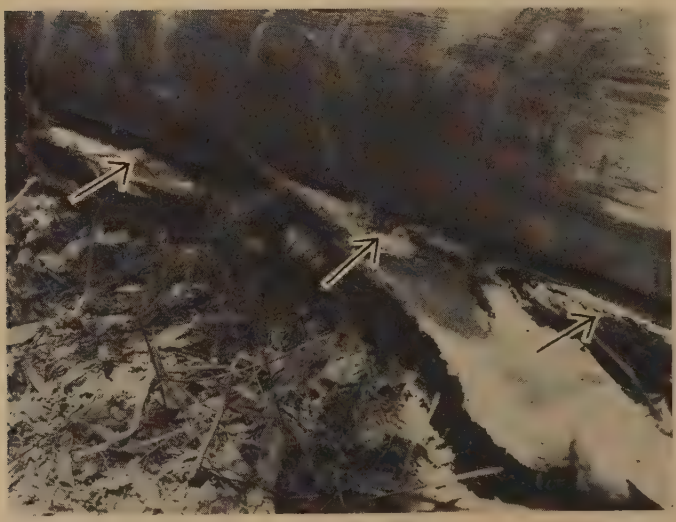


Fig. 5.

Borer Attacks on Hoop Pine Logs, Indicated by "Threads" from Tunnel Entrances.



A



B

Fig. 6.

A, "Threads" from Borer Attacks on the Sides and Under Surfaces of a Log; and B, Borer "Dust" of *Platypus froggatti* in an Angle between Bark and Wood.

amount of wood chewed away by this species, a large amount of dust accumulates below the entrance (Figure 8). The threads and accumulated dust provide obvious evidence of attacks.

Fungal growth, on which the larvae feed, lines the tunnel walls and sometimes may cause tunnel blockages. This material is at first of a greyish colour but later turns black, giving the characteristic shot-burn appearance to the tunnel walls, while mycelial penetration stains the adjacent wood a bluish colour.

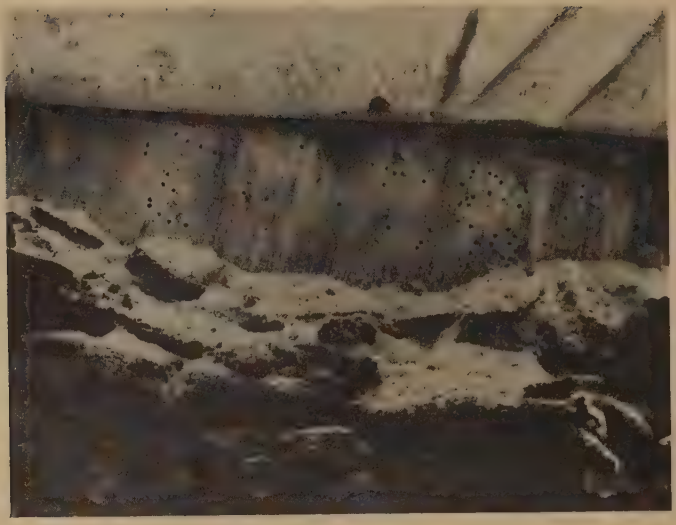
BREEDING SOURCES.

Breeding in virgin areas is restricted to decadent trees, suppressed branches and various injuries and is less with *P. froggatti* than with the other species.

Where logging operations are in progress suitable host material is provided in abundance. This includes hoop pine and many other tree species

Fig. 7.

End of a Hoop Pine Log, Indicating Width of Sapwood.



A

B

Fig. 8.

A, Borer "Dust" from Tunnels of *Platypus froggatti*; and B, Transverse Section of Log, showing Tunnels of *Platypus froggatti*.

smashed or bruised by the falling pine trees (Figure 9). Breeding is thus favoured and gains impetus, so in a year or two from the commencement of logging the beetle population becomes high.

Fig. 9.
Damage to Stand and Canopy by Felling Operations.

Logging of hoop pine gives particular impetus to the breeding of *P. froggatti*. As attacks by the other borers are normally spread over many hosts it may be expected that *P. froggatti* will dominate in attacks on hoop pine logs felled in or adjacent to cut-over areas. In virgin areas, on the other hand, where breeding of *P. froggatti* is restricted, the other borer species should dominate.

SEASONAL ACTIVITY.

While detailed quantitative investigations on beetle populations and activity have not been made, experience has shown that there are definite seasonal variations. Both cold weather and dry weather are unfavourable. The

former directly limits activity and logs felled during the winter months are not attacked. Dry weather in the warmer months restricts the period or radius of chemotropic attraction or tends to confine the beetles within the original host tissue and attacks on fresh logs are negligible. Isolated storm rains in early summer stimulate activity for short periods. However, with the onset of more frequent rain in summer or early autumn moist conditions obtain for several months. The chemotropic attraction then is great; further, the beetles are either directly or indirectly stimulated to emerge from old host tissues and seek new ones. Consequently there is continuous activity amongst a large free-living borer population and logs felled in this period may be subjected to heavy attacks.

CONDITIONS IN THE EXPERIMENTAL AREA.

The experimental area was located on State Forest Reserve 399, Parish of Emu Vale, 25 miles east of Warwick. This reserve extends over a large area of precipitous country on the western watershed of the Great Dividing Range, covering the sources of the Condamine River and many of its tributaries. Numerous ravines and valleys extend well into the range and the intervening spurs lead back to mountain peaks over 4,000 feet high. Rainfall is comparatively high and is estimated to be double the recorded annual average of 28 inches at Killarney, on the foothills of the western slope.

The more readily accessible timber in the lower reaches of the valleys had previously been cut. Access to the timber being harvested was by zigzagging tracks along the watercourses. Logging operations, especially haulage, were therefore intimately related to climatic conditions.

At the time of this investigation, hoop pine was the only species being harvested. Logs felled near the beds of the valleys were barked and remained at the stump until snigged to forest ramps. The commercial boles of trees felled on the higher slopes were "shot" into the valleys after barking, and there cut into log lengths (Figure 10) before being snigged to the ramps.

Logging operations were of necessity carried out mostly in limited periods determined by rainfall. In spite of difficulties, operations continued reasonably well for eight or nine months of the year. During the remaining months, usually in late summer and early autumn, persistent rain frequently made the forest inaccessible. Consequently it was usual to increase logging operations prior to this period so as to provide a reserve of logs for continuous milling operations during the wet weather.

The onset of the wet season is irregular and unpredictable, and when it commenced early large quantities of logs remained sometimes for many months on the forest floor, or on ramps. Borer attacks then became concentrated on the logs, more particularly on those near previously logged areas.

The essential part of the investigations, therefore, was to devise a means of protection for the logs against borer attacks especially applicable to those likely to be confined to the forest during wet weather.

Fig. 10.

Boles Cut into Logs after being "Shot" into the Valley during Logging Operations in the Cryptocarya Creek Area.

Fig. 11.

Experimental Logs in the Crypt carya Creek Area strewn along the Valley.

CONTROL EXPERIMENTS.

Trial Sites.

Control experiments were established on two sites, in the Menura Creek and Cryptocarya Creek areas. The Menura Creek site was on comparatively even ground adjacent to a cut-over area. Because of proximity to water and snigging tracks, the logs were treated where they fell. The Cryptocarya Creek site was part of a virgin stand. After the boles were "shot" and cut, the logs, strewn along the bed of the valley, were treated there (Figure 11).

Log Material.

As far as was possible, small mill logs were used. These allowed sufficient surface area without involving a large volume in the event of wastage occurring. A few were of ply quality, but most were graded "logs" and "tops." In all, 33 trees were felled, providing 127 logs which gave 44,563 super. feet of timber and 11,697 square feet of log surface.

Chemicals Used.

Since the borer species encountered do not consume wood particles, the materials selected were designed to act mainly as repellants and deterrents. They were applied as solutions soon after felling and barking of the logs.

With the work of Craighead (1922) as a guide, interest was centred on creosote. This was used alone and with diluents and other chemicals as indicated by the results of prior laboratory mixing tests. The diluents and some other non-creosote materials were included as treatments for comparative purposes. The various materials used are detailed later.

Methods and Rates of Application.

All treatments, except when applied as bands, were made with a knapsack spray pump, the logs being rolled to ensure a cover on all surfaces. An arbitrary rate of one gallon to 125-150 square feet of log surface was chosen as providing a liberal application and was adopted as the standard for this investigation. In practice this rate was reached when the solution commenced to run and drip from the log. The treatments were randomized and most had five replications.

Assessment of Protection.

Assessment of log protection was determined from a count of all borer entrance holes appearing on the logs after treatment. At the same time the borer species operating on each log were noted and an estimate made of relative abundance. (See Appendix 1.) For comparative purposes the following ratings were used to evaluate borer attacks.

No attack—no borer holes.
Slight attack—1 to 5 holes per 100 sq. ft. of log surface.
Light attack—6 to 20 holes per 100 sq. ft. of log surface.
Moderate attack—21 to 50 holes per 100 sq. ft. of log surface.
Heavy attack—more than 50 holes per 100 sq. ft. of log surface.

This is a severe rating. It was chosen partly because the borers can make extensive tunnel systems within the log. The main reasons, however, were to impose a high degree of protection and to obtain a critical division between treatments without using an unmanageable number of replicates.

The position of attack on the logs was determined by dividing the circumference into five sectors, as follows:—"a," the under surface; "e," the upper surface; "b," "c" and "d," the intervening side surfaces. (Discussion given in Appendix 2.)

FIRST EXPERIMENT.

Menura Creek Site.

Felling on the Menura Creek site commenced on January 11 and extended to the next day. Ten trees provided the 33 logs used. This involved a total of 9,472 super. feet of timber and 2,785 square feet of log surface; the logs therefore averaged 287·0 super. feet and 84·4 square feet of surface area. Treatments were applied mainly on the day of felling, and not later than the following day. Details of log dimensions and dates of felling are given in Table 1.

Table 1.

DATA ON LOGS AND TREATMENTS ON THE MENURA CREEK SITE.

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 1—Creosote Emulsion.									
3 ..	16	58	280	80·8	3	11–1–39	11–1–39		
5 ..	16	46	176	63·6	2	11–1–39	11–1–39		
10 ..	14	61	271	75·2	1	12–1–39	12–1–39	3	140
14 ..	15	74	428	98·8	1	12–1–39	12–1–39		
19 ..	22	53	322	100·2	3	12–1–39	12–1–39		
Total	..	..	1,477	418·6	..	..	..	..	..
Mean	16·6	58·4	295·4	83·7	..	..	..	..	..
Treatment 2—Creosote and Kerosene.									
8 ..	20	45	211	77·3	2	11–1–39	11–1–39		
12 ..	19	50	247	81·8	3	11–1–39	11–1–39		
16 ..	20	62	400	107·3	3	12–1–39	12–1–39	3	151
21 ..	16	68	385	95·7	1	12–1–39	12–1–39		
25 ..	16	65	352	91·2	2	12–1–39	12–1–39		
Total	..	..	1,595	453·3	..	..	..	..	..
Mean	18·2	58·0	319·0	90·7	..	..	..	..	..
Treatment 3—Creosote and "Lignasan."									
2 ..	16	65	352	91·2	2	11–1–39	11–1–39		
4 ..	15	54	228	70·6	1	11–1–39	11–1–39		
9 ..	19	38	143	55·2	3	11–1–39	12–1–39	3	134
15 ..	13	71	341	82·6	2	12–1–39	12–1–39		
20 ..	20	59	363	102·3	2	12–1–39	12–1–39		
Total	..	..	1,427	401·9	..	..	..	..	..
Mean	16·6	57·4	285·4	80·4	..	..	..	..	..

Table 1.—*continued.*

DATA ON LOGS AND TREATMENTS ON THE MENURA CREEK SITE—*continued.*

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 4—Creosote and "Dowicide G."									
7 ..	17	51	230	75·3	1	11–1–39	11–1–39		
11 ..	16	57	271	79·5	2	11–1–39	11–1–39		
22 ..	20	56	327	96·8	2	12–1–39	12–1–39	3	147
26 ..	19	56	310	92·2	3	12–1–39	12–1–39		
28 ..	18	62	360	96·8	1	12–1–39	12–1–39		
Total	..	..	1,498	440·6	..	..	..	..	..
Mean	18·0	56·4	299·6	88·1	..	..	..	..	..
Treatment 5—Creosote (Standard Rate).									
23 ..	19	48	228	78·7	3	12–1–39	12–1–39		
29 ..	20	55	315	95·2	2	12–1–39	12–1–39	1¾	139
31 ..	14	57	237	70·0	1	12–1–39	12–1–39		
Total	..	..	780	243·9	..	..	..	..	..
Mean	17·7	53·3	260·0	81·3	..	..	..	..	..
Treatment 6—Creosote (One-fifth Standard Rate).									
24 ..	15	76	451	101·3	1	12–1–39	12–1–39		
30 ..	22	43	212	80·7	3	12–1–39	12–1–39	⅜	670
32 ..	20	50	260	86·0	2	12–1–39	12–1–39		
Total	..	..	923	268·0	..	..	..	..	..
Mean	19·0	56·3	307·7	89·3	..	..	..	..	..
Treatment 7—Creosote Bands.									
13 ..	24	42	221	85·9	4	11–1–39	12–1–39	¼	..
17 ..	22	57	372	108·0	4	12–1–39	12–1–39		
Total	..	..	593	193·9	..	..	..	..	..
Mean	23·0	49·5	296·5	96·9	..	..	..	..	..
Treatment 8—Untreated.									
1 ..	14	70	357	87·3	1	11–1–39	..	..	..
6 ..	17	40	142	58·5	3	11–1–39	..	..	..
18 ..	14	64	299	79·2	1	12–1–39	..	..	..
27 ..	20	46	220	78·9	4	12–1–39	..	..	..
33 ..	16	44	161	60·9	3	12–1–39	..	..	..
Total	..	..	1,179	364·8	..	..	..	..	..
Mean	16·2	52·8	235·8	73·0	..	..	..	..	..

All treatments in this trial included creosote grade K55 Standard of the Standards Association of Australia and were as follows:—

1. Creosote emulsion (1 gal. creosote, 1 lb. soft soap, 4 gal. water).
2. Creosote and Kerosene (1 gal. creosote, 4 gal. kerosene).
3. Creosote and "Lignasan" (1 gal. creosote, 1 lb. soft soap, 2 oz. "Lignasan," 4 gal. water).
4. Creosote and "Dowicide G" (1 gal. creosote, 1 lb. soft soap, 2½ oz. "Dowicide G," 4 gal. water).
5. Creosote alone (standard rate).
6. Creosote alone (one-fifth of standard rate).
7. Creosote alone, applied in bands.
8. Untreated.

Treatments of creosote mixed with other materials were applied at the standard rate. Creosote alone, as a complete cover, was used at two different rates—standard and one-fifth standard. The latter gave a creosote cover comparable to the creosote component of the mixed solutions. All sprays readily adhered to the fresh log surface. The creosote bands around the circumference of the logs were six inches wide and spaced at intervals varying from one to four feet. Treatments and rates of application are shown in Table 1.

Cryptocarya Creek Site.

Felling on the Cryptocarya Creek site commenced also on January 11 and continued until January 16. Eleven trees provided the 42 logs. These involved a total of 18,155 super. feet of timber and 4,262 square feet of log surface; the logs therefore averaged 432·3 super. feet content and 106·2 square feet of surface area. Treatments in some instances were made on the day of felling, some on the following day and a few on the second day after felling. Details of log dimensions and dates of felling are given in Table 2.

The spray solutions in this trial included some of the diluents of creosote used in the Menura Creek trial, and other solutions of prior unknown value as log protectants against borer attacks.

The treatments were as follows:—

9. White oil and nicotine sulphate (1 gal. white oil, 1 pint nicotine sulphate, 20 gal. water).
10. Red oil (1 gal. red oil, 20 gal. water).
11. Washing soda solution (1 lb. washing soda, 1 gal. water).
12. "Borokil."
13. Resin-caustic soda-fish oil (10 lb. resin, 3 lb. caustic soda, 1½ lb. fish oil, 20 gal. water).
14. Kerosene.
15. Soft soap solution (1 lb. soft soap, 4 gal. water).
16. "Du Pont Le 5" (1 lb. "Du Pont Le 5," 16 gal. water).
17. "Du Pont Le 6" (1 lb. "Du Pont Le 6," 16 gal. water).
18. Untreated.

Some of these solutions were used with the idea that the oil or other constituent might repel the borers or mask attraction, or that the alkalinity might change the log surface and render it unattractive.

The materials used in treatments 12, 13, 14, 16 and 17 adhered to the fresh log surface reasonably well, and one application was sufficient to give a uniform distribution. Adherence was poor with treatments 9, 10, 11 and 15; run-off was excessive with one application and therefore two successive light applications were made. Most of these solutions were applied at a rate within the range of the standard, the upper area limit being slightly exceeded with kerosene and the soft soap solution. Treatments and rates of application are given in Table 2.

Table 2.

DATA ON LOGS AND TREATMENTS ON THE CRYPTOCARYA CREEK SITE..

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 9—White Oil and Nicotine Sulphate.									
34 ..	14	57	237	70·0	1	11–1–39	13–1–39		
42 ..	14	101	744	126·9	2	12–1–39	13–1–39		
51 ..	14	74	399	92·6	2	11–1–39	13–1–39	4½	127
62 ..	20	88	807	155·0	2	12–1–39	13–1–39		
64 ..	15	93	676	126·0	1	12–1–39	14–1–39		
Total	..	..	2,863	570·5	..	..	..	..	..
Mean	15·4	82·6	572·6	114·1	..	..	..	..	..
Treatment 10—Red Oil.									
35 ..	14	53	205	64·9	2	11–1–39	13–1–39		
41 ..	14	105	804	134·8	1	12–1–39	13–1–39		
49 ..	13	49	163	55·8	4	11–1–39	13–1–39	3	128
54 ..	14	54	213	66·0	4	11–1–39	13–1–39		
60 ..	13	55	205	63·2	5	11–1–39	13–1–39		
Total	..	..	1,590	384·7	..	..	..	..	..
Mean	13·6	63·2	318·0	76·9	..	..	..	..	..
Treatment 11—Washing Soda Solution.									
46 ..	14	70	357	87·3	1	11–1–39	14–1–39		
55 ..	18	47	207	69·8	5	11–1–39	14–1–39		
58 ..	14	77	432	96·1	3	11–1–39	14–1–39	3½	134
61 ..	14	95	658	120·7	1	12–1–39	14–1–39		
70 ..	18	61	349	95·5	3	16–1–39	16–1–39		
Total	..	..	2,003	469·4	..	..	..	..	..
Mean	15·6	70·0	400·6	93·9	..	..	..	..	..
Treatment 12—"Borokil."									
45 ..	15	89	619	120·3	5	12–1–39	14–1–39		
53 ..	14	59	254	72·8	3	11–1–39	14–1–39	2	145
56 ..	14	78	444	97·9	1	11–1–39	14–1–39		
Total	..	..	1,317	291·0	..	..	..	..	..
Mean	14·3	75·3	439·0	97·0	..	..	..	..	..

Table 2—continued.

DATA ON LOGS AND TREATMENTS ON THE CRYPTOCARYA CREEK SITE.

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 13—*Resin-Caustic Soda-Fish Oil.*									
36 ..	14	48	168	58·7	3	11–1–39	13–1–39		
38 ..	20	48	240	82·7	1	11–1–39	13–1–39	2	131
43 ..	14	95	658	120·7	3	12–1–39	13–1–39		
Total	..	..	1,066	262·1	..	..	..	..	..
Mean	16·0	63·7	355·3	87·4	..	..	..	..	..
Treatment 14—*Kerosene.*									
37 ..	20	43	193	73·6	4	11–1–39	13–1–39		
39 ..	14	39	111	46·8	2	11–1–39	13–1–39	1½	166
44 ..	16	91	690	128·0	4	12–1–39	13–1–39		
Total	..	..	994	248·4	..	..	..	..	..
Mean	16·7	57·7	331·3	82·8	..	..	..	..	..
Treatment 15—*Soft Soap Solution.*									
50 ..	13	44	131	49·9	5	11–1–39	14–1–39		
59 ..	13	59	236	67·9	4	11–1–39	14–1–39	1½	156
63 ..	16	82	560	116·9	3	12–1–39	14–1–39		
Total	..	..	927	234·7	..	..	..	..	..
Mean	14·0	61·7	309·0	78·2	..	..	..	..	..
Treatment 16—"*Du Pont Le* 5."									
48 ..	14	56	229	68·8	3	11–1–39	14–1–39		
65 ..	15	89	619	120·3	2	12–1–39	14–1–39		
68 ..	26	79	845	178·3	1	16–1–39	16–1–39	4½	142
73 ..	22	61	426	115·9	2	16–1–39	16–1–39		
75 ..	24	71	630	157·7	1	16–1–39	16–1–39		
Total	..	..	2,749	641·0	..	..	..	..	..
Mean	20·2	71·2	549·8	128·2	..	..	..	..	..
Treatment 17—"*Du Pont Le* 6."									
47 ..	14	62	280	76·3	2	11–1–39	14–1–39		
66 ..	20	80	667	140·2	3	12–1–39	14–1–39		
69 ..	25	75	732	162·6	2	16–1–39	16–1–39	5	136
72 ..	27	75	791	175·1	1	16–1–39	16–1–39		
76 ..	23	63	475	125·3	2	16–1–39	16–1–39		
Total	..	..	2,945	679·5	..	..	..	..	..
Mean	21·8	71·0	589·0	135·9	..	..	..	..	..
Treatment 18—*Untreated.*									
52 ..	14	64	299	79·2	2	11–1–39			
67 ..	17	75	498	112·6	4	12–1–39			
71 ..	17	52	239	76·8	4	16–1–39			
74 ..	28	49	350	117·0	3	16–1–39			
77 ..	20	55	315	95·2	3	16–1–39			
Total	..	..	1,701	480·8	..	..	..	..	..
Mean	19·2	59·0	340·2	96·2	..	..	..	..	..

First Examination on the Menura Creek Site.

The weather experienced while the various treatments on the Menura Creek site were applied was hot and dry. This was not conducive to borer activity and while these conditions continued there was little evidence of attacks even on untreated logs. Following about an inch of rain during the early morning of January 18, increased borer activity was evident immediately, and by the next day progress observations on borer attacks on the experimental logs were possible. At this time all borer holes were not counted and the attacks were determined by inspection. Results are given in Table 3.

Table 3.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE. (SEVEN TO EIGHT DAYS AFTER TREATMENT AND TWO DAYS AFTER RAIN.)

Log No.	Attack Rating.	Log No.	Attack Rating.
Treatment 1— *Creosote Emulsion.*		*Treatment* 2— *Creosote and Kerosene*—	
3	Slight	8	Slight
5	Nil	12	Nil
10	Nil	16	Nil
14	Nil	21	Nil
19	Nil	25	Slight
Treatment 3— *Creosote and "Lignasan"*		*Treatment* 4— *Creosote and "Dowicide G"*	
2	Moderate	7	Slight
4	Nil	11	Slight
9	Slight	22	Slight
15	Light	26	Nil
20	Light	28	Nil
Treatment 5— *Creosote alone (standard rate)*		*Treatment* 6— *Creosote alone (one-fifth standard rate)*	
23	Nil	24	Nil
29	Nil	30	Nil
31	Nil	32	Nil
Treatment 7— *Creosote Bands*		*Treatment* 8— *Untreated*	
13	Slight in 4 feet spacings, but as close as 6 inches from a band	1	Moderate
17		6	Slight
		18	Moderate
		27	Heavy
		33	Moderate

Second Examination on the Menura Creek Site.

During the three-weeks period after the first examination further rain fell, providing a continuation of conditions favourable to borer activity. Attacks were intensified and a full count was made on February 8 (i.e., four weeks after the treatments were applied). The results are detailed in Table 4.

Table 4.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE.
(FOUR WEEKS AFTER TREATMENT.)

Log No.	Borer Species.	Position of Attack.	Number of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 1—Creosote Emulsion.					
3	1	a, b	18	0·22	Moderate
5	1, 2	a, b	47	0·74	Heavy
10	1	a	4	0·05	Slight
14	..	..	0	0·00	Nil
19	1	a, b	5	0·05	Slight
Treatment 2—Creosote and Kerosene.					
8	1, 2, 3	a, b, c	53	0·69	Heavy
12	1	a, b, c	14	0·17	Light
16	1	a, b, c	15	0·14	Light
21	1, 2	a, b, c	14	0·25	Moderate
25	1	a, b, c	9	0·10	Light
Treatment 3—Creosote and "Lignasan."					
2	1, 2	a, b	65	0·71	Heavy
4	1, 2	a, b	8	0·11	Light
9	1, 2	a, b, c	16	0·29	Moderate
15	1, 2, 3	a, b, c	32	0·39	Moderate
20	1, 2, 3	a, b, c	59	0·58	Heavy
Treatment 4—Creosote and "Dowicide G."					
7	1, 2, 3	a, b, c	58	0·77	Heavy
11	1, 2, 3	a, b, c	39	0·49	Moderate
22	1, 2	b, c	34	0·35	Moderate
26	1, 2	a, b, c	35	0·38	Moderate
28	1	b	4	0·04	Slight
Treatment 5—Creosote (Standard Rate).					
23	..	..	0	0·00	Nil
29	..	..	0	0·00	Nil
31	..	..	0	0·00	Nil
Treatment 6—Creosote (One-fifth Standard Rate).					
24	..	..	0	0·00	Nil
30	1	b	2	0·03	Slight
32	..	..	0	0·00	Nil
Treatment 7—Creosote Bands.					
13	1, 2, 3	a, b, c	..	..	Heavy*
17	1, 2	a, b, c	..	..	Moderate*
Treatment 8—Untreated.					
1	1, 2, 3	a, b, c, d, e	193	2·21	Heavy
6	1, 2, 3	a, b, c, d, e	120	2·05	Heavy
18	1, 2, 3	a, b, c	230	2·90	Heavy
27	1, 2, 3	a, b, c	175	2·22	Heavy
33	1, 2, 3	a, b, c	187	3·07	Heavy

* Attacks occurred on exposed wood between all bands.

Analysis.

Necessary difference for significance = ·413 (5 per cent. level); ·563 (1 per cent. level)

Treatment.	Mean,	Significantly less at 1 per cent. Level than—
1	0·212	8
2	0·270	8
3	0·416	8
4	0·406	8
8	2·490	..
5	0·000	3, 4, 8
6	0·010	3, 4, 8

5 and 6 are not included in general analysis, because of low variability.

It was noted that three species were operating. These are referred to in Table 4 by numbers as follows:—1. *P. froggatti;* 2. *P. australis;* and 3. *C. omnivorus.* It was shown later that other species attacked logs on the Menura Creek site. While these possibly were present at this examination, they were not detected.

Third Examination on the Menura Creek Site.

As certain of the creosote treatments were promising, the logs concerned were allowed to remain in the forest. Humid weather continued, but rain prevented further examination until March 21 (i.e., 10 weeks after the treatments were applied). The results of this examination are given in Table 5.

Table 5.

Assessment of Borer Attacks on Some Creosoted Logs on the Menura Creek Site. (Ten Weeks after Treatment.)

Log No.	Borer Species.	Position of Attack.	Number of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 5—Creosote Alone (Standard Rate).					
23	1	a	3	0·04	Slight
29	..	..	0	0·00	Nil
31	..	..	0	0·00	Nil
Treatment 6—Creosote Alone (One-fifth Standard Rate).					
24	1, 2	a, b	12	0·12	Light
30	1	b	9	0·11	Light
32	1	a	4	0·05	Slight

Examination of Logs on the Cryptocarya Creek Site.

An examination of logs on the Cryptocarya Creek site was made on February 9, four weeks after the treatments were applied. The results obtained are given in Table 6. These logs were in a virgin stand and a

greater number of borer species was present than was shown on the Menura Creek site. The species are referred to in the table as follows:—1. *P. froggatti;* 2. *P. australis;* 3. *C. omnivorus;* 4. *P. semigranosus* and *P. subgranosus;* 5. *X. perforans* and *X. eucalypticus.*

Table 6.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE CRYPTOCARYA CREEK SITE.
(FOUR WEEKS AFTER TREATMENT.)

Log No.	Borer Species.	Position of Attack.	Number of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 9—White Oil and Nicotine Sulphate.					
34	..	..	0	0·00	Nil
42	3, 4, 5	b, c, d, e	20	0·16	Light
57	3	b	4	0·04	Slight
62	2, 3, 4, 5	b, c, d	32	0·21	Moderate
64	2, 3, 4, 5	c, d	19	0·15	Light
Treatment 10—Red Oil.					
35	3, 4, 5	b, c, d, e	13	0·20	Light
41	3, 4	b, c	5	0·04	Slight
49	..	..	0	0·00	Nil
54	..	..	0	0·00	Nil
60	3	b	2	0·03	Slight
Treatment 11—Washing Soda Solution.					
46	3, 4, 5	c, d	11	0·13	Light
55	3, 4, 5	a, b, c	40	0·57	Heavy
58	3, 4, 5	c, d, e	0	0·09	Light
61	3, 4, 5	b, c, d	125	1·04	Heavy
70	3, 5	b, c, d	15	0·16	Light
Treatment 12—"Borokil."					
45	3, 4, 5	b, c, d	15	0·13	Light
53	3	c	12	0·17	Light
56	3, 4, 5	b, c, d, e	41	0·42	Moderate
Treatment 13—Resin-Caustic Soda-Fish Oil.					
36	3, 4, 5	b, c, d	8	0·14	Light
38	3	b	2	0·02	Slight
43	3, 4, 5	a, b, c	40	0·33	Moderate
Treatment 14—Kerosene.					
37	3, 4, 5	b, c, d	35	0·48	Moderate
39	3, 5	c	3	0·06	Light
44	3, 4, 5	a, b, c, d	120	0·94	Heavy

Table 6—continued.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE CRYPTOCARYA CREEK SITE.
(FOUR WEEKS AFTER TREATMENT.)

Log No.	Borer Species.	Position of Attack.	Number of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 15—*Soap Solution.*					
50	3	c	1	0·02	Slight
59	3	b, c	3	0·04	Slight
63	2, 3, 4, 5	b, c, d, e	93	0·80	Heavy
Treatment 16—"*Du Pont Le* 5."					
48	3	c	2	0·03	Slight
65	1, 2, 3	a, b, c	32	0·27	Moderate
68	3, 5	b, c, d	28	0·16	Light
73	3, 4, 5	b, c, d	23	0·20	Light
75	3	c, d, e	11	0·07	Light
Treatment 17—"*Du Pont Le* 6."					
47	3, 4	b, c	13	0·17	Light
66	1, 2, 3	a, b, c	52	0·37	Moderate
69	3, 4	b, c, d	27	0·17	Light
72	3, 4, 5	b, c, d, e	51	0·29	Moderate
76	3, 4	a, b, c, d	11	0·09	Light
Treatment 18—*Untreated.*					
52	3, 4	a, b, c	84	1·06	Heavy
67	1, 2, 3	a, b, c, d, e	205	1·82	Heavy
71	3, 4	b, c, d	21	0·27	Moderate
74	3, 4, 5,	b, c, d, e	176	1·50	Heavy
77	3, 4	b, c	59	0·62	Heavy

Analysis.

Necessary difference for significance—

	5% Level.	1 % Level.
5 v 5	·413	·555
5 v 3	·476	·641
3 v 3	·533	·716

Treatment.	Replicates.	Mean.	Significance.
9	5	0·112	
10	5	0·054	14 significantly less than 18 at the 5 per cent. level. All other treatments significantly less than 18 at the 1 per cent. level
11	5	0·398	
12	3	0·240	
13	3	0·163	
14	3	0·493	
15	3	0·287	
16	5	0·146	
17	5	0·218	
18	5	1·054	

SECOND EXPERIMENT.

Menura Creek Site.

As weather conditions continued to be favourable to borer activity a second experiment was commenced immediately to confirm the results of the promising treatments in the first experiment and to test certain variations. This work was carried out in the Menura Creek area partly on and partly adjacent to the site of the first experiment, so that borer populations present would provide a severe test for the treatments.

Felling commenced on February 15 and was completed two days later. Twelve trees provided 52 logs. These involved 16,936 super. feet of timber and 4,650 square feet of log surface, with an average content of 325·7 super. feet and an average surface area of 89·4 square feet. Log dimensions and dates of felling are given in Table 7.

The treatments used in this experiment were as follows:—

19. Creosote alone (standard rate).
20. Creosote alone (one-fifth standard rate).
21. Cresote alone (one-third standard rate).
22. Creosote Emulsion (*a*) (1 gal. creosote, 1 lb. soft soap, 4 gal. water).
23. Creosote Emulsion (*b*) (1 gal. creosote, ½ lb. soft soap, 2 gal. water).
24. Creosote and Kerosene (1 gal. creosote, 2 gal. kerosene).
25. Creosote and "Lignasan" (1 gal. creosote, ½ lb. soft soap, 1⅓ oz. "Lignasan," 2 gal. water).
26. Cresote and "Dowicide G" (1 gal. cresote, ½ lb. soft soap, 1½ oz. "Dowicide G," 2 gal. water).
27. "Du Pont Le 5" (standard rate).
28. "Du Pont Le 6" (standard rate).
29. Red Oil (standard rate).
30. Untreated.

Creosote alone was used at three different rates. Two of the rates were comparable to those used in the first experiment; the third was intermediate and intended to approximate the cover rate of that proportion of creosote in the mixtures with kerosene, "Lignasan," "Dowicide G" and Creosote Emulsion (*b*).

All logs were treated at the stump, the treatments being applied in the same manner and mostly at the same general rate as in the first experiment. Some treatments were made on the day of felling, others on the following day. The treatments and rates of application are given in Table 7.

Table 7.

DATA ON LOGS AND TREATMENTS ON THE MENURA CREEK SITE (SECOND EXPERIMENT).

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 19—Creosote (a).									
89 ..	14	59	254	72·8	1	15–2–39	16–2–39		
93 ..	16	74	456	105·0	2	16–2–39	16–2–39		
98 ..	15	66	340	87·6	2	16–2–39	16–2–39	$3\frac{1}{4}$	134
103 ..	14	68	337	84·4	3	16–2–39	16–2–39		
107 ..	14	68	337	84·4	2	16–2–39	16–2–39		
Total	..	..	1,724	434·2	..	..	..	..	..
Mean	14·6	67·0	344·8	86·8	..	..	..	..	..
Treatment 20—Creosote (One-fifth Standard Rate).									
90 ..	18	52	253	81·1	2	15–2–39	16–2–39		
96 ..	22	51	298	96·6	5	16–2–39	16–2–39	App.	Approx.
97 ..	14	70	357	87·3	1	16–2–39	16–2–39	$\frac{3}{4}$	600
102 ..	14	73	388	90·8	2	16–2–39	16–2–39		
106 ..	14	73	388	90·8	1	16–2–39	16–2–39		
Total	..	..	1,684	446·6	..	..	..	..	..
Mean	16·4	63·8	336·8	89·3	..	..	..	..	..
Treatment 21—Creosote (One-third Standard Rate).									
78 ..	14	59	254	72·8	1	15–2–39	16–2–39		
83 ..	14	55	220	67·7	2	15–2–39	16–2–39	App.	Approx.
86 ..	15	55	236	72·3	1	15–2–39	16–2–39	$1\frac{1}{8}$	380
92 ..	13	78	412	91·4	1	16–2–39	16–2–39		
100 ..	29	51	393	126·3	4	16–2–39	16–2–39		
Total	..	..	1,515	430·5	..	..	..	..	..
Mean	17·0	59·6	303·0	86·1	..	..	..	..	..
Treatment 22—Creosote Emulsion (a).									
80 ..	26	40	217	88·6	3	15–2–39	15–2–39		
84 ..	18	50	234	77·6	3	15–2–39	15–2–39	App.	Approx.
88 ..	21	41	184	73·6	3	15–2–39	15–2–39	2	130
Total	..	..	635	239·8	..	..	..	..	..
Mean	21·7	43·7	211·7	79·9	..	..	..	..	..
Treatment 23—Creosote Emulsion (b).									
79 ..	14	56	229	68·9	2	15–2–39	15–2–39		
82 ..	15	59	272	77·8	1	15–2–39	15–2–39		
87 ..	18	47	207	69·8	2	15–2–39	15–2–39	3	128
91 ..	20	46	220	78·9	3	15–2–39	16–2–39		
94 ..	15	66	340	87·6	3	16–2–39	16–2–39		
Total	..	..	1,268	383·0	..	..	..	..	..
Mean	16·4	54·8	253·6	76·6	..	..	..	..	..

Table 7—continued.

DATA ON LOGS AND TREATMENTS ON THE MENURA CREEK SITE (SECOND EXPERIMENT).

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 24—Creosote and Kerosene.									
99 ..	16	59	290	82·7	3	16–2–39	16–2–39		
101 ..	14	77	432	96·1	1	16–2–39	16–2–39		
108 ..	14	63	289	78·0	3	17–2–39	17–2–39	3½	131
115 ..	20	69	496	120·1	5	17–2–39	17–2–39		
120 ..	16	58	280	80·8	4	17–2–39	17–2–39		
Total	..	..	1,787	457·7	..	..	..	..	..
Mean	16·0	65·2	357·4	91·5	..	..	..	..	..
Treatment 25—Creosote and "Lignasan."									
95 ..	20	59	363	103·7	4	16–2–39	16–2–39		
105 ..	22	53	322	100·2	5	16–2–39	16–2–39		
109 ..	20	58	350	100·2	4	16–2–39	16–2–39	3½	138
112 ..	13	84	478	98·6	2	17–2–39	17–2–39		
119 ..	14	64	299	79·2	3	17–2–39	17–2–39		
Total	..	..	1,812	481·9	..	..	..	..	..
Mean	17·8	63·6	362·4	96·4	..	..	..	..	..
Treatment 26—Creosote and "Dowicide G."									
104 ..	21	62	420	112·5	4	16–2–39	17–2–39		
110 ..	20	50	260	86·0	5	16–2–39	17–2–39		
113 ..	14	79	455	99·1	3	17–2–39	17–2–39	3½	131
118 ..	14	68	337	84·4	2	17–2–39	17–2–39		
124 ..	15	57	254	74·8	4	17–2–39	17–2–39		
Total	..	..	1,726	456·8	..	..	..	..	..
Mean	16·8	63·2	345·2	91·4	..	..	..	..	..
Treatment 27—"Du Pont Le 5."									
117 ..	15	74	428	98·8	1	17–2–39	17–2–39		
123 ..	14	62	280	76·3	3	17–2–39	17–2–39	2¼	125
128 ..	20	62	400	107·3	3	17–2–39	17–2–39		
Total	..	..	1,108	282·4	..	..	..	..	..
Mean	16·3	66·0	369·3	94·1	..	..	..	..	..
Treatment 28—"Du Pont Le 6."									
114 ..	16	74	456	105·0	4	17–2–39	17–2–39		
121 ..	14	71	367	88·5	1	17–2–39	17–2–39	2¼	125
127 ..	14	70	357	87·3	2	17–2–39	17–2–39		
Total	..	..	1,180	280·8	..	..	..	..	..
Mean	14·7	71·7	393·3	93·6	..	..	..	..	..

Table 7—continued.

DATA ON LOGS AND TREATMENTS ON THE MENURA CREEK SITE (SECOND EXPERIMENT).

Log No.	Length.	Girth.	Timber Content.	Surface Area.	Position on Tree.	Date Felled.	Date Treated.	Quantity of Spray Used.	Surface Area per Gallon.
	Ft.	In.	Sup. Ft.	Sq. Ft.				Gal.	Sq. Ft.
Treatment 29—Red Oil.									
116 ..	30	58	526	148·5	6	17–2–39	17–2–39	$2\frac{3}{4}$	121
125 ..	20	51	271	88·1	5	17–2–39	17–2–39		
126 ..	14	76	421	94·9	1	17–2–39	17–2–39		
Total	..	..	1,218	331·5	..	..	..	..	..
Mean	21·3	61·7	406·0	110·5	..	..	..	..	..
Treatment 30—Untreated.									
81 ..	22	42	202	78·9	4	15–2–39	..	..	..
85 ..	22	46	242	86·6	4	15–2–39	..	..	..
111 ..	22	41	193	77·1	1	16–2–39	..	..	..
122 ..	14	66	318	82·1	2	17–2–39	..	..	..
129 ..	22	53	322	100·2	4	17–2–39	..	..	..
Total	..	..	1,277	424·9	..	..	..	..	..
Mean	20·4	49·6	255·4	85·0	..	..	..	..	..

First Examination.

Moist conditions were prevailing when this trial was started and further rain fell a few days after the applications were completed. Borer attacks readily developed and preliminary observations were made two weeks after treatment. The results are given in Table 8.

Table 8.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE. (SECOND EXPERIMENT).

(TWO WEEKS AFTER TREATMENT.)

Log No.	Attack Rating.	Log No.	Attack Rating.
Treatment 19— *Creosote* (*Standard Rate*)— No attack on any log		*Treatment* 20— *Creosote* (*One-fifth Standard Rate*)— No attack on any log	
Treatment 21— *Creosote* (*One-third Standard Rate*)— No attack on any log		*Treatment* 22— *Creosote and Kerosene*— No attack on any log	
Treatment 23— *Creosote Emulsion* (*a*)— No attack on any log		*Treatment* 24— *Creosote Emulsion* (*b*)— No attack on any log	

Table 8—continued.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE. (SECOND EXPERIMENT).

(TWO WEEKS AFTER TREATMENT.)

Log No.	Attack Rating.	Log No.	Attack Rating.
Treatment 25— *Creosote and "Lignasan"*—		*Treatment* 26— *Creosote and "Dowicide G"*—	
95	Slight	104	Nil
105	Slight	110	Light
109	Light	113	Slight
112	Nil	116	Slight
119	Nil	124	Slight
Treatment 27— *"Du Pont Le 5"*—		*Treatment* 28— *"Du Pont Le 6"*—	
117	Nil	114	Slight
123	Light	121	Light
128	Nil	127	Slight
Treatment 29— *Red Oil*—		*Treatment* 30— *Untreated*—	
116	Nil	81	Nil
125	Light	85	Slight
126	Nil	111	Light
		122	Light
		129	Moderate

Second Examination.

Continued wet weather prevented a complete examination until March 30 (i.e., six weeks after the treatments were made). The results of this count are given in Table 9. It was shown that, in a few instances, particularly on untreated logs, all five species of borers recorded on the Cryptocarya Creek site were present. The reference numbers for these in Table 9 are the same as those used previously (page 92).

Table 9.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE (SECOND EXPERIMENT). (SIX WEEKS AFTER TREATMENT.)

Log No.	Borer Species.	Position of Attack.	No. of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 19—*Creosote* (*Standard Rate*).					
89	1	*b*	5	0·07	Light
93	1	*b*	3	0·03	Slight
98	..	..	0	0·00	Nil
103	..	..	0	0·00	Nil
107	..	..	0	0·00	Nil

Table 9—continued.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE (SECOND EXPERIMENT). (SIX WEEKS AFTER TREATMENT.)

Log No.	Borer Species	Position of Attack.	Number of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
Treatment 20—Creosote (One-fifth Standard Rate).					
90	1, 3	b, c	28	0·35	Moderate
96	1, 3	b, c	10	0·10	Light
97	1	b	17	0·20	Light
102	1	b	5	0·05	Slight
106	1, 2	b, c	38	0·42	Moderate
Treatment 21—Creosote (One-third Standard Rate).					
78	..	..	0	0·00	Nil
83	1	b	4	0·06	Light
86	..	..	0	0·00	Nil
92	..	..	0	0·00	Nil
100	1, 3, 5	a, b, c	43	0·26	Moderate
Treatment 22—Creosote Emulsion (a).					
80	3	b	8	0·09	Light
84	1	a, b	13	0·17	Light
88	1	b	8	0·11	Light
Treatment 23—Creosote Emulsion (b).					
79	1	b	1	0·02	Slight
82	..	..	0	0·00	Nil
87	..	..	0	0·00	Nil
91	3	c	3	0·04	Slight
94	1	a, b	16	0·18	Light
Treatment 24—Creosote and Kerosene.					
99	1	b	7	0·09	Light
101	..	..	0	0·00	Nil
108	1, 3	a	5	0·06	Light
115	..	..	0	0·00	Nil
120	1	b	4	0·05	Slight
Treatment 25—Creosote and "Lignasan."					
95	1	a	43	0·42	Moderate
105	1	b	18	0·18	Light
109	1, 3	a, b, c	51	0·51	Heavy
112	1	b	12	0·12	Light
119	1	a, b	15	0·19	Light
Treatment 26—Creosote and "Dowicide G."					
104	1, 3, 5	a, b, c, d	125	1·11	Heavy
110	1, 2, 3	a, b, c	116	1·35	Heavy
113	1, 3, 4, 5	b, c, d, e	52	0·53	Heavy
118	1, 3	a, b	32	0·38	Moderate
124	1, 3	b, c, d	34	0·46	Moderate

Table 9—continued.

ASSESSMENT OF BORER ATTACKS ON LOGS ON THE MENURA CREEK SITE (SECOND EXPERIMENT). (SIX WEEKS AFTER TREATMENT.)

Log No.	Borer Species.	Position of Attack.	No. of Borer Holes.	Holes per Sq. Ft.	Attack Rating.
		Treatment 27—"*Du Pont Le* 5."			
117	1, 4	a, b, c	27	0·27	Moderate
123	1	b, c, d	41	0·54	Heavy
128	1, 3, 4	a, b, c, d, e	51	0·48	Moderate
		Treatment 28—"*Du Pont Le* 6."			
114	1	b, c, d	28	0·27	Moderate
121	1, 3, 4	a, b, c, d	87	0·95	Heavy
127	1	b, c	19	0·22	Moderate
		Treatment 29—*Red Oil.*			
116	1	b, c	19	0·13	Moderate
125	1, 3, 4	b, c, d	87	0·99	Heavy
126	1, 3, 4	a, b, c, d	105	1·11	Heavy
		Treatment 30—*Untreated.*			
81	1, 3, 4, 5	b, c, d, e	217	2·75	Heavy
85	1, 2, 3, 4, 5	a, b, c, d, e	198	2·18	Heavy
111	1, 2, 3, 4, 5	a, b, c, d, e	185	2·40	Heavy
122	1, 3, 4, 5	b, c, d, e	203	2·47	Heavy
129	1, 3, 5	b, c, d, e	254	2·54	Heavy

Analysis.

Necessary difference for significance—

	5% level.	1% level.
5 v 5	·300	·402
5 v 3	·347	·464
3 v 3	·388	·519

Treatment.	Replicates.	Mean.	Significantly less than—	
			5 % Level.	1 % Level.
19	5	0·020	26, 27, 28, 29, 30	26, 28, 29, 30
20	5	0·224	26, 29, 30	26, 29, 30
21	5	0·064	26, 27, 28, 29, 30	26, 29, 30
22	3	0·123	26, 29, 30	26, 29, 30
23	5	0·048	26, 27, 28, 29, 30	26, 29, 30
24	5	0·040	26, 27, 28, 29, 30	26, 29, 30
25	5	0·284	26, 29, 30	26, 30
26	5	0·766	30	30
27	3	0·430	30	30
28	3	0·490	30	30
29	3	0·743	30	30
30	5	2·468	..	..

DISCUSSION.

All non-creosote treatments reduced the intensity of borer attacks but the best of them was significantly inferior to creosote. Materials mixed with creosote in themselves added nothing to the value of the creosote; in fact, "Dowicide G" and "Lignasan" decreased its value.

Creosote diluted with soap solution, in the proportion of 1 to 2, provided an economic control. However, preparing the hot soap solution required for thorough emulsification places a limitation on the general use of the mixture in the forest. Creosote diluted with kerosene, in the proportion of 1 to 2, also provided an economic control, which was readily usable in the forest.

Creosote used alone at a rate of distribution comparable to that proportion of it in the emulsion or kerosene mixture was as effective as the mixed treatments. At the rate of 1 gal. to 140 sq. ft. of log surface it gave virtually complete protection for 10 weeks. However, creosote bands as close as one foot did not counter the chemotropic attraction of untreated surfaces. The effectiveness of the complete log cover therefore would seem to be due to a change which the creosote imposes on the attracting agents.

This investigation demonstrated that for practical purposes K 55 standard creosote applied to hoop pine logs within two days of felling, at the rate of one gallon to 150 square feet of surface, as a complete log cover, provides effective protection from borer attacks.

Immediately following this work creosote emulsion (1 part creosote, 2 parts soap solution) was adopted as a routine treatment, and subsequent borer infestation was within economic limits. Further, shortly after the results were released to the trade, creosote came into use in New Guinea for treating export logs; borer attacks in shipments of treated logs were negligible and in striking contrast to the extremely heavy attacks of earlier shipments.

Browne (1949) in Malaya has cast some doubt on the value of creosote for protecting logs. However, Taylor and Hadlington (1950), working on hardwood logs in the rain-forest of northern New South Wales, reaffirm that creosote is the most effective protectant against borers.

ACKNOWLEDGMENTS.

The assistance given by Mr. H. J. Myers, proprietor of the sawmills concerned, and by officers of the Forestry Department, is gratefully acknowledged. The Commonwealth Institute of Entomology examined material of the species of *Xyleborus* variously identified as *X. testaceus* Walk. and *X. fuscobrunneus* Eichh., and determined the specimens to be *X. perforans* Woll. Statistical analyses of the experimental data were carried out by Mr. P. B. McGovern, M.A., B.Sc., Biometrician in the Division of Plant Industry.

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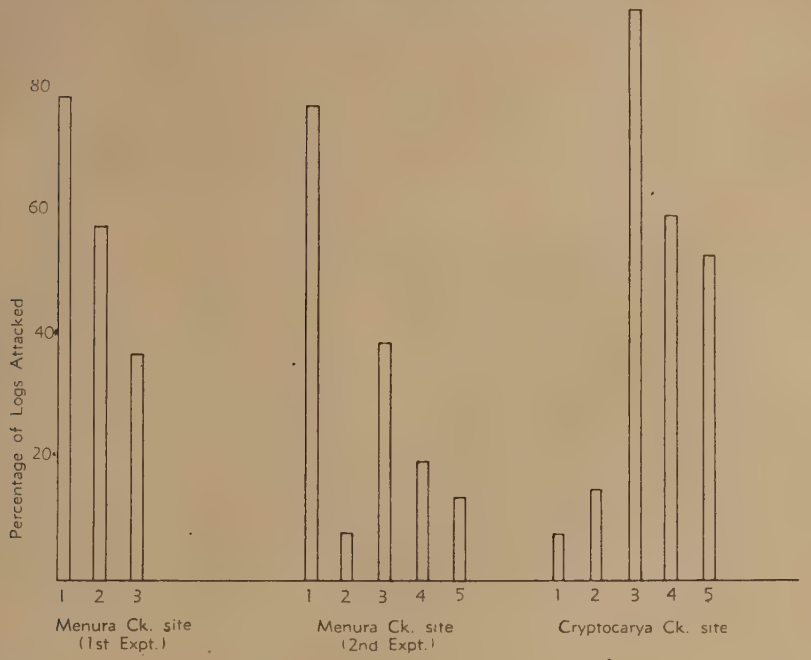
APPENDIX 1.

RELATIVE ABUNDANCE OF BORER SPECIES.

Quantitative observations were not made on borer populations; however, relative abundance was indicated by the percentage of logs attacked and estimates of the percentage of holes by each species. These are given in Figure 10. They confirmed the anticipation that *P. froggatti* would dominate the attacks on the Menura Creek sites, adjacent to a cut-over area, and that the smaller species would dominate on the Cryptocarya Creek site located within a virgin stand.



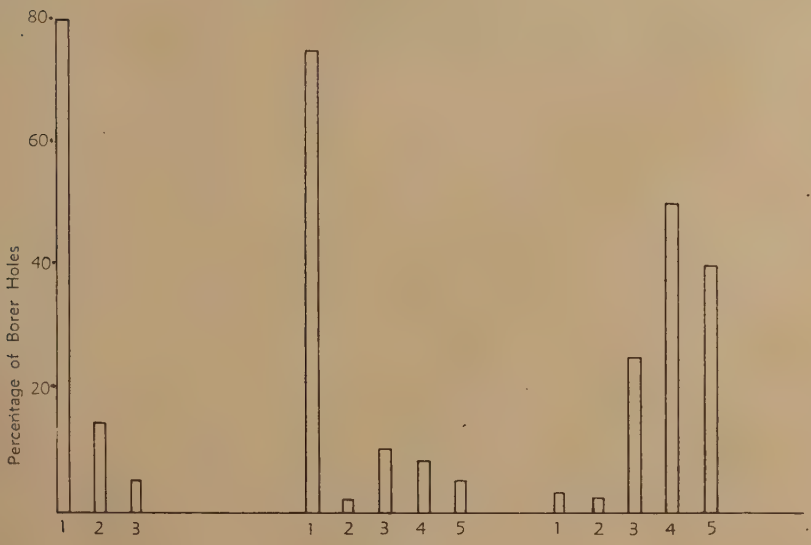


Fig. 10.

Relative Abundance of Borer Species as Shown by Percentage of Logs Attacked and Percentage of Borer Holes. The numbers refer to 1, *Platypus froggati;* 2, *P. australis;* 3, *Crossotarsus omnivorus;* 4, *Platypus semigranosus* and *P. subgranosus;* 5, *Xyleborus perforans* and *X. eucalypticus.*

APPENDIX 2.

POSITION OF ATTACKS ON LOGS.

The positions of borer attacks on the logs were recorded and are given in Tables 6, 7 and 11. The data proved to have no direct influence on control treatments but nevertheless are of technical interest. On the Menura Creek site (first experiment), where the canopy was severely destroyed and rain was intermittent, attacks dominated by *P. froggatti* were greatest on the lower sectors—"a," "b" and "c"—of both treated and untreated logs. The treatments, however, precluded attacks on the upper sectors, "d" and "e." In the second experiment rain was almost continuous and all untreated logs were attacked on each sector except "a," which in many instances was in contact with the ground. *P. froggatti* again dominated on sectors "a" and "b." The smaller species attacked on all sectors but dominated in sectors "d" and "e." Treated logs were attacked mostly on sectors "a," "b," and "c" and were dominated by *P. froggatti.* On the Cryptocarya Creek site, with an undestroyed canopy and intermittent rain, attacks dominated by the smaller species were greatest on sectors "b," "c," and "d" on both treated and untreated logs. The percentages of logs attacked in each sector for the three experiments are given in Figure 11.

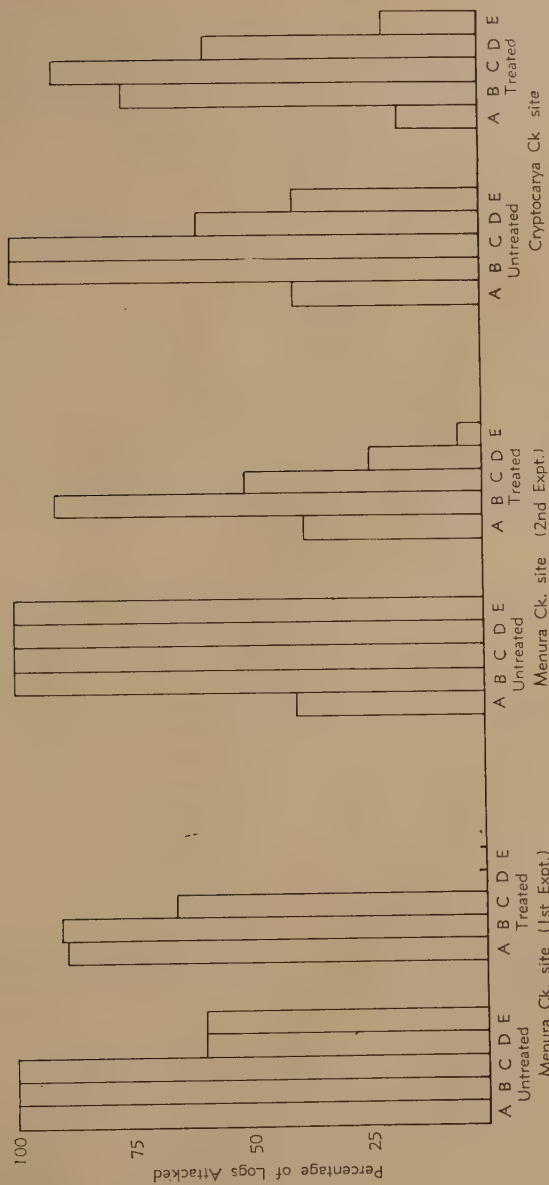


Fig. 11.

Percentages of Logs Attacked on Each Sector of Untreated and Treated Logs.

OBSERVATIONS ON THE USE OF THE HAMMOND SYSTEM OF PIG CARCASE APPRAISAL IN QUEENSLAND.

By K. J. HUTCHINSON, B.Sc.Agr., Assistant Husbandry Officer, Pig Branch, Division of Animal Industry.

SUMMARY.

An examination of measurements of 950 carcases entered in fresh and cured pig carcase competitions conducted in Queensland, and judged by the Hammond system, was made.

In the sections body length, eye muscle thickness and leg length, the Hammond standards favoured certain weight ranges. No bias was shown for the character backfat thickness.

No overall bias was shown by a comparison of total marks and weight range.

Mean values for various measurements of fresh and cured carcases are compared.

INTRODUCTION.

During recent years, in an endeavour to improve the quality of pig carcases produced in Queensland, the Australian Meat Board and various district agricultural show societies have conducted competitions for both fresh and cured carcases. The Hammond or Smithfield method of carcase appraisal (Davidson, Hammond, Swain and Wright, 1937) has provided the basis for competition judging. However, since the prevailing export market requirement has been for carcases of bacon weight, attention has been focussed on carcases within the range of 120-180 lb. dressed weight.

The competitions have provided a considerable volume of data and these have been analysed firstly to define present bacon carcase performance, as measured against the Hammond ideal, of pigs reared in the Queensland environment, and secondly to determine whether the carcase weight of entries has any effect on such comparisons.

MATERIALS AND METHODS.

Measurements for 950 carcases (379 fresh and 571 cured) were available. The characters considered in the analysis are body length, eye muscle thickness, back fat thickness and leg length. Each was studied individually and separately for fresh and cured sides. For each of them a regression line was fitted for the character versus weight class, on the assumption that the lineal

relationship would be adequate for the 120-180 lb. weight range considered, which proved to be correct. The mean increment for increase in weight for each character was determined and compared with the standards set down by the Hammond appraisal method to determine whether there was any difference favouring particular weight ranges. Carcase weight was based on the cold dressed figure in both cured and fresh carcase competitions.

Finally, from differences between observed results in cured and fresh sides an estimate of the mean change in measurement resulting from the curing process or other factors was made.

RESULTS.

Body Length.

This measurement gives an indication of the length of the valuable loin joint which can be cut from the carcase. The higher the ratio of length to carcase weight, the greater is the value of the carcase for cutting purposes.

The marks allotted for body length under the Hammond system of appraisal are given in Table 1, and Table 2 is a summary of the body length measurements of the 950 carcases included in the survey.

Table 1.

HAMMOND SYSTEM MARKS FOR BODY LENGTH IN THE 120–179 LB. RANGE.

Marks.	Carcase Weight (Lb.)											
	120 to 124	125 to 129	130 to 134	135 to 139	140 to 144	145 to 149	150 to 154	155 to 159	160 to 164	165 to 169	170 to 174	175 to 179
	Body Length (mm.).											
1 ..	670	680	690	700	710	720	730	740	750	760	770	780
2 ..	675	685	695	705	715	725	735	745	755	765	775	785
3 ..	680	690	700	710	720	730	740	750	760	770	780	790
4 ..	685	695	705	715	725	735	745	755	765	775	785	795
5 ..	690	700	710	720	730	740	750	760	770	780	790	800
6 ..	695	705	715	725	735	745	755	765	775	785	795	805
7 ..	700	710	720	730	740	750	760	770	780	790	800	810
8 ..	705	715	725	735	745	755	765	775	785	795	805	815
9 ..	710	720	730	740	750	760	770	780	790	800	810	820
10 ..	715	725	735	745	755	765	775	785	795	805	815	825
11 ..	720	730	740	750	760	770	780	790	800	810	820	830
12 ..	725	735	745	755	765	775	785	795	805	815	825	835
13 ..	730	740	750	760	770	780	790	800	810	820	830	840
14 ..	735	745	755	765	775	785	795	805	815	825	835	845
15 ..	740	750	760	770	780	790	800	810	820	830	840	850
16 ..	745	755	765	775	785	795	805	815	825	835	845	855
17 ..	750	760	770	780	790	800	810	820	830	840	850	860
18 ..	755	765	775	785	795	805	815	825	835	845	855	865
19 ..	760	770	780	790	800	810	820	830	840	850	860	870
20 ..	765	775	785	795	805	815	825	835	845	855	865	875

Table 2.

SUMMARY OF DATA FOR BODY LENGTH IN FRESH AND CURED CARCASES.

Carcase Weight.	Fresh.			Hammond Ideal.	Cured.		
	No.	Observed.	Calculated.		No.	Observed.	Calculated.
Lb.		mm.	mm.	mm.		mm.	mm.
120–124 ..	12	761·3	748·4	765	43	726·8	727·7
125–129 ..	25	755·7	755·3	775	34	739·0	734·9
130–134 ..	37	758·8	762·2	785	58	739·3	742·2
135–139 ..	45	770·0	769·2	795	77	753·5	749·5
140–144 ..	35	770·5	776·1	805	76	753·8	756·7
145–149 ..	36	783·5	783·0	815	59	763·2	764·0
150–154 ..	48	791·9	790·0	825	60	772·3	771·2
155–159 ..	24	800·7	796·9	835	49	775·7	778·5
160–164 ..	34	799·0	803·8	845	46	782·7	785·8
165–169 ..	41	811·3	810·8	855	39	801·6	793·0
170–174 ..	22	814·1	817·7	865	20	795·0	800·3
175–179 ..	20	831·6	824·6	875	10	809·1	807·6
Totals ..	379				571		

——	Ideal.	Fresh.	Cured.	Mean.
	mm.	mm.	mm.	mm.
Increase/5 lb.	10	6·93	7·26	7·12
s.e.	...	±·374	±·359	..

The results indicate that the observed rate of increase in length (a mean of 7·12 mm. for each 5 lb. increase in carcase weight for both cured and fresh sides) is considerably lower than the Hammond standard (10·00 mm. per 5 lb. increase). The deficiency in fresh carcases is 16·6 mm. in the 120-124 lb. range and 50·4 mm. in the 175-179 lb. range, and throughout the whole range these differences from the standard are sufficient to favour the lighter carcase and penalise the heavier carcase.

The deficiency in carcase length shown by competition entries suggests that there is considerable room for improvement in the body length-carcase weight relationship of the general pig population.

In Figure 1, linear regression lines of body length on carcase weight have been fitted to the observed results. It is obvious from these lines that the "rate of growth" for body length of pigs in Queensland is not as high as the Hammond standard. Presumably this standard was fixed after examination of a range of carcases from Great Britain and the Dominions, but the data have not been published. Whether or not this comparative lack of response of body length to increase in weight is peculiar to the Queensland environment*, to the particular sample of data, or to some other factor would be difficult to determine.

* This is not likely, since subsequent analyses of competition results in some other Australian States reveal similar trends.

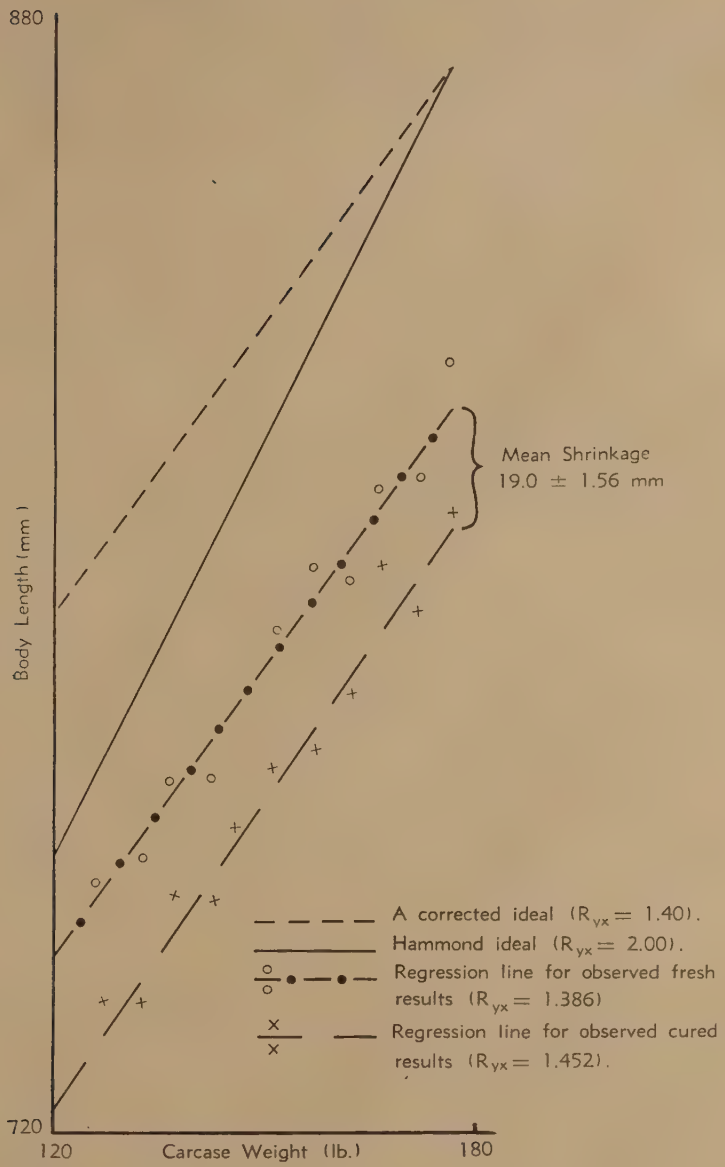


Fig. 1.

Regression Lines for Body Length on Carcase Weight.

The explanation may lie in differences in the breed composition of the Queensland carcases and those on which the Hammond standard was based. Undoubtedly differences in breed maturity would affect the relationship between carcase character and weight range. The 371 fresh carcases included in the current survey had the following breed composition:—

	Per cent.
Crossbred	42
Large White	34
Berkshire	18
Tamworth	3
Wessex Saddleback	3

If desired, a corrected "ideal" could be fixed at any position relative to the observed regression line, and provided it is parallel to it would correct any bias favouring the lighter ranges. An example of such an "ideal" is shown in Figure 1.

Many of the competitions which provided the data for analysis, particularly those sponsored by show societies, were conducted for cured bacon carcases. For the judging of these, the Hammond tables for fresh carcases were used. The question has often arisen as to whether these tables could be adjusted for judging cured sides by making appropriate allowances for differences in measurement encountered between the two classes.

An estimate of the mean change in length as a result of the curing process, or peculiar to competition conditions, has been made; it has the value 19·0 ± 1·56 mm. Such an estimate is quite valid if both the regression lines are considered to be characteristic of carcase competition entries as a whole. It is probable, however, that there would be differences in both the shrinkage capacity of individual carcases and the curing processes at various centres.

In the special case of body length, a most important factor is that fresh carcases are measured "on the hook," whereas the cured sides have been judged "on the table." Lush (1936) reported that Danish workers estimated an average "stretching effect" of 15 mm. in body length when carcases are measured "on the hook."

Eye Muscle Thickness.

The thickness or depth of the eye muscle is used in the Hammond system as an index of the total weight of muscle in the carcase. When viewed in proportion to carcase weight, an estimate can be made of the relative amount of lean meat in the carcase.

The marks allotted in the Hammond system for thickness of eye muscle in relation to carcase weight are as shown in Table 3. Table 4 summarizes the data for this relationship obtained from measurements made in Queensland, and Figure 2 is a graphic representation of the values.

The observed rate of increase in eye muscle thickness was found to be 2·468 mm. for each 20 lb. increase in body weight, compared with the Hammond

Table 3.

HAMMOND SYSTEM MARKS FOR EYE MUSCLE THICKNESS IN THE 120–179 LB. RANGE.

Marks.	Carcase Weight (Lb.)		
	120 to 139.	140 to 159.	160 to 179.
	Thickness of Eye Muscle (mm.).		
1	32	33	34
3	33	34	35
5	34	35	36
7	35	36	37
9	36	37	38
11	37	38	39
13	38	39	40
14	39	40	41
15	40	41	42
16	41	42	43
17	42	43	44
18	43	44	45
19	44	45	46
20	45	46	47
21	46	47	48
22	47	48	49
23	48	49	50
24	49	50	51
25	50	51	52
26	51	52	53
27	52	53	54
28	53	54	55

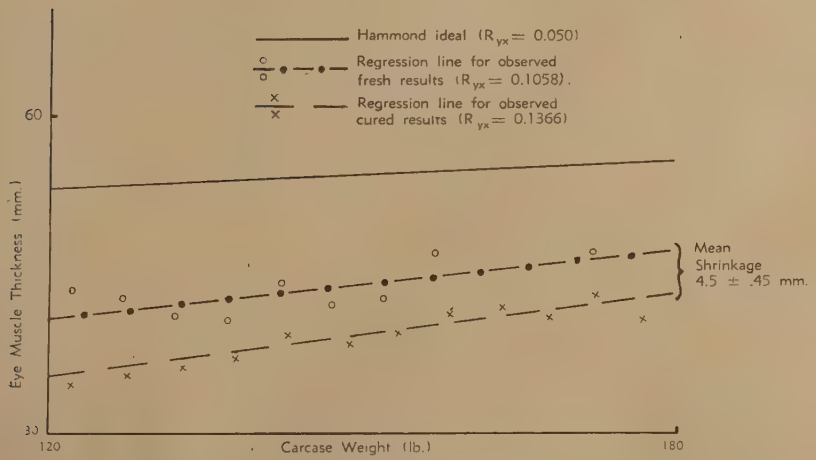

Hammond ideal (R_{yx} = 0.050)
Regression line for observed fresh results (R_{yx} = 0.1058).
Regression line for observed cured results (R_{yx} = 0.1366)
60
30
Eye Muscle Thickness (mm.)
120
Carcase Weight (lb.)
180
Mean Shrinkage 4.5 ± .45 mm.

Fig. 2.

Regression Lines for Eye Muscle Thickness on Carcase Weight.

Table 4.

SUMMARY OF DATA FOR EYE MUSCLE THICKNESS IN FRESH AND CURED CARCASES.

Carcase Weight.	Fresh.			Hammond Ideal.	Cured.		
	No.	Observed.	Calculated.		No.	Observed.	Calculated.
Lb.		mm.	mm.	mm.		mm.	mm.
120–124 ..	12	43·3	40·5		43	34·8	35·2
125–129 ..	25	42·2	41·0	53	34	35·7	35·9
130–134 ..	37	41·1	41·6		58	36·5	36·6
135–139 ..	45	40·7	42·1		77	37·2	37·2
140–144 ..	35	43·7	42·6		76	38·9	37·9
145–149 ..	36	42·0	43·2	54	59	37·8	38·6
150–154 ..	48	42·3	43·7		60	39·1	39·3
155–159 ..	24	46·6	44·2		49	40·0	40·0
160–164 ..	34	45·2	44·7		46	41·7	40·7
165–169 ..	41	45·6	45·3	55	39	40·8	41·4
170–174 ..	22	46·5	45·8		20	42·3	42·0
175–179 ..	20	45·7	46·3		10	40·8	42·7
Totals ..	379				571		

——	Ideal.	Fresh.	Cured.	Mean.
	mm.	mm.	mm.	mm.
Increase/5 lb.	·250	·529	·683	·617
	..	±·1039	±·1060	..

standard increase of 1·0 mm. per 20 lb. The difference favours the heavier carcases.

A suggested correction of the present standard would be to divide the scale into 10 lb. carcase weight classes. The increments would then be 1·0 mm. per 10 lb. increase in weight. This should eliminate most of the small bias favouring the heavier carcases.

The estimate for mean shrinkage in eye muscle thickness in cured carcases was 4·5 ± 0·45 mm.

Backfat Thickness.

The marks allotted for thickness of fat over the loin in the Hammond system are given in Table 5.

The data for the character obtained in the survey are summarized in Table 6.

Statistical analysis did not reveal any significant difference between the observed regression coefficient and that of the Hammond standard.

Backfat thickness differs from the characters already considered in that the ideal is intermediate between the two extremes. For the purpose of analysis there appeared to be no disadvantage attaching to bulking the results of the "underfat" and the "overfat" carcases. However, the distribution of these in the results considered is of interest (Table 7).

Table 5.

HAMMOND SYSTEM MARKS FOR BACKFAT THICKNESS IN THE 120–179 LB. RANGE.

Marks.	Carcase Weight (Lb.)					
	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	170 to 179
Thickness of Fat over Loin (mm.).						
1	7	8	9	10	11	12
4	8	9	10	11	12	13
7	9	10	11	12	13	14
10	10	11	12	13	14	15
12	11	12	13	14	15	16
14	12	13	14	15	16	17
15	..	14	15	16	17	18
16	13	15	16	17	18	19
17	14	16	17	18	19	20
18	15	17	18	19	20	21
19	16	18	19	20	21	22
20	17	19	20	21	22	23
19	18	20	21	22	23	24
18	19	21	22	23	24	25
17	20	22	23	24	25	26
16	21	23	24	25	26	27
14	22	24	25	26	27	28
12	23	25	26	27	28	29
10	24	26	27	28	29	30
7	25	27	28	29	30	31
4	26	28	29	30	31	32
1	27	29	30	31	32	33

Table 6.

SUMMARY OF DATA FOR BACKFAT THICKNESS IN FRESH AND CURED CARCASES.

Carcase Weight.	Fresh.			Hammond Ideal.	Cured.		
	No.	Observed.	Calculated.		No.	Observed.	Calculated.
Lb.		mm.	mm.	mm.		mm.	mm.
120–124 ..	12	14·7	16·6	17	43	18·0	18·7
125–129 ..	25	16·0	17·3		34	19·1	19·3
130–134 ..	37	19·1	18·0	18	58	20·7	20·0
135–139 ..	45	18·6	18·7		77	20·9	20·6
140–144 ..	35	20·9	19·4	20	76	21·2	21·3
145–149 ..	36	20·3	20·1		59	22·3	21·9
150–154 ..	48	20·7	20·8	21	60	21·1	22·6
155–159 ..	24	19·8	21·6		49	23·9	23·2
160–164 ..	34	22·7	22·3	22	46	24·7	23·9
165–169 ..	41	23·0	23·0		39	23·2	24·5
170–174 ..	22	22·9	23·7	23	20	23·8	25·2
175–179 ..	20	24·8	24·4		10	30·0	25·8
Totals ..	379				571		

Table 6—continued.

—	Ideal.	Fresh.	Cured.	Mean.
Increase/5 lb.	mm. 1 to ·5	mm. ·714	mm. ·649	mm. ·677
	..	±·0816	±·0874	..

Table 7.

DISTRIBUTION OF CARCASES ON THE BASIS OF FATNESS.

—	Percentage of Carcases Examined.	
	Fresh.	Cured.
Underfat	46·7	40·3
Ideal	10·3	7·5
Overfat	43·0	52·2

It would appear that the underfinished pig is represented just as strongly as the overfat type, so apparently farmers entering carcases in competitions are aware of the undesirability of overfatness.

The small but quite regular expansion in backfat thickness in the cured carcases (1·8+0·37 mm.) is of interest. This would contribute in part to the percentage of overfat cured carcases.

Leg Length.

Length of leg is a measurement which is correlated with the amount of bone in the carcase. The marks given for this character in the Hammond system are shown in Table 8, and the observations on fresh carcases are summarized in Table 9. The cured carcases are not considered, as leg length could not be measured in the cured carcase competitions.

The observed increment was found to be 3·59 mm. for each 5 lb. increase in body weight (R_{yx} = 0·718). This was significantly different from the present standard increase of 5·00 mm. per 5 lb. increase (R_{yx} = 1·00), and indicates that a considerable bias in favour of the heavier weight ranges exists.

Carcase Distribution According to Weight Range.

Though the Hammond system provides for the allotment of marks in special circumstances for suitability of carcase weight (Table 10), this aspect of appraisal is not generally applied in competitions in Australia. The view taken is that any carcase within the 120-180 lb. dressed weight range, with optimum measurements for essential competition characters, will make ideal bacon.

Table 8.

HAMMOND SYSTEM MARKS FOR LEG LENGTH IN THE 120–179-LB. RANGE.

Marks.	Carcase Weight (Lb.)											
	120 to 124	125 to 129	130 to 134	135 to 139	140 to 144	145 to 149	150 to 154	155 to 159	160 to 164	165 to 169	170 to 174	175 to 179
	Leg Length (mm.).											
1	570	575	580	585	590	595	600	605	610	615	620	625
2	569 to 560	574 to 565	579 to 570	584 to 575	589 to 580	594 to 585	599 to 590	604 to 595	609 to 600	614 to 605	619 to 610	624 to 615
3	559 to 550	564 to 555	569 to 560	574 to 565	579 to 570	584 to 575	589 to 580	594 to 585	599 to 590	604 to 595	609 to 600	614 to 605
4	549 to 540	554 to 545	559 to 550	564 to 555	569 to 560	574 to 565	579 to 570	584 to 575	589 to 580	594 to 585	599 to 590	604 to 595
5	539	544	549	554	559	564	569	574	579	584	589	594

Table 9.

SUMMARY OF DATA FOR LEG LENGTH IN FRESH CARCASES.

Carcase Weight.	Leg Length.			
	No.	Observed.	Calculated.	Hammond Ideal.
Lb.		mm.	mm.	mm.
120–124	12	566·5	558·5	539
125–129	25	560·6	562·1	544
130–134	37	564·1	565·7	549
135–139	45	569·1	569·3	554
140–144	35	567·2	572·8	559
145–149	36	576·6	576·4	564
150–154	48	584·7	580·0	569
155–159	24	587·0	583·6	574
160–164	34	586·1	587·2	579
165–169	41	591·0	590·8	584
170–174	22	588·9	594·4	589
175–179	20	600·2	598·0	594
	379	..	..	..

—	Ideal.	Fresh.
	mm.	mm.
Increase/5 lb.	5	3·59
	..	±·329

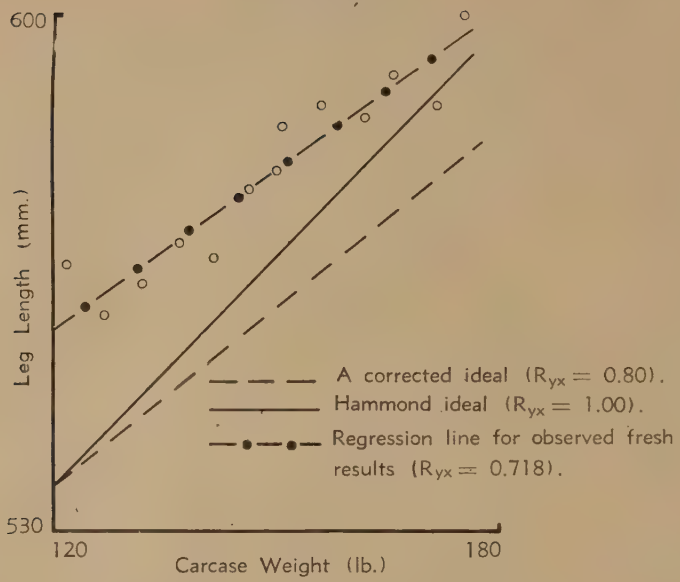


Fig. 3.

Regression Lines for Body Length on Carcase Weight.

Table 10.

HAMMOND SYSTEM MARKS FOR SUITABILITY OF CARCASE WEIGHT IN BACON PIGS.

Marks.	Carcase Weight. (Lb.)
1	110–114
4	115–119
7	120–124
10	125–129
13	130–134
15	135–154
14	155–159
13	160–164
12	165–169
11	170–174
9	175–179
7	180–184
5	185–189
3	190–194
1	195–199

Under the Hammond system the ideal carcase weight for the Wiltshire trade was defined as being within the 135-154 lb. range. The width of this range was supposed to allow for breed and cross maturity differences.

By restricting the competitions to carcases within the 120-180 lb. range, the application of marks for suitability of carcase weights loses much of its value. In any case, it can be seen from the distribution of the data considered in this study that 46 per cent. of the entries fall within the ideal range (Table 11).

Table 11.

FREQUENCY VERSUS WEIGHT RANGE FOR FRESH AND CURED CARCASE DATA.

Weight Range.	Fresh.	Cured.	Total.
120–124 ..	12	43	55
125–129 ..	25	34	59
130–134 ..	37	58	95
135–139 ..	45	77	122
140–144 ..	35	76	111
145–149 ..	36	59	95
150–154 ..	48	60	108
155–159 ..	24	49	73
160–164 ..	34	46	80
165–169 ..	41	39	80
170–174 ..	22	20	42
175–179 ..	20	10	30
Totals ..	379	571	950

Table 12.

REGRESSION COEFFICIENTS FOR MEASURED CHARACTERS.

		Hammond.	Observed.	Remarks.
Fresh—	Body Length	2·00	1·386	Significant Difference
	Eye Muscle Thickness ..	0·050	0·1058	Significant Difference
	Backfat Thickness ..	0·100	0·1428	No Significant Difference
	Leg Length	1·00	0·7180	Significant Difference
Cured—	Body Length	2·00	1·452	Significant Difference
	Eye Muscle Thickness ..	0·050	0·1366	Significant Difference
	Backfat Thickness ..	0·100	0·1298	No Significant Difference

The distribution, as shown in Figure 4, indicates a slight tendency to favour lighter carcases. However, it is not suggested that competitors are aware that weight range may affect competition results. It is unfortunate that extreme ranges include relatively few individuals in their classes, but the regression lines that have been calculated for the characters in question were based on weighted means and thus due importance was placed on class frequency.

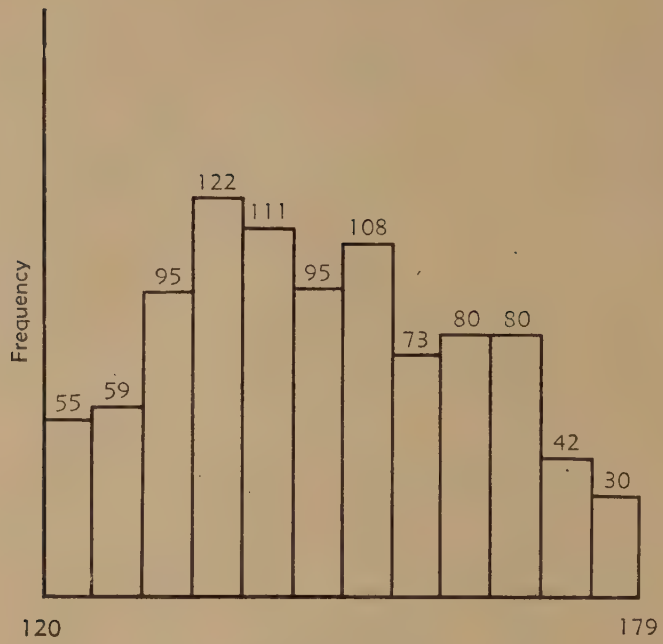


Fig. 4.

Distribution of Carcases According to Weight.

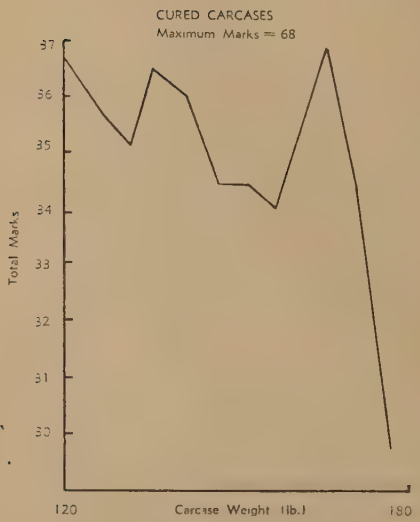


Fig. 5.

Relationship of Total Marks to Weight—Cured Carcases.

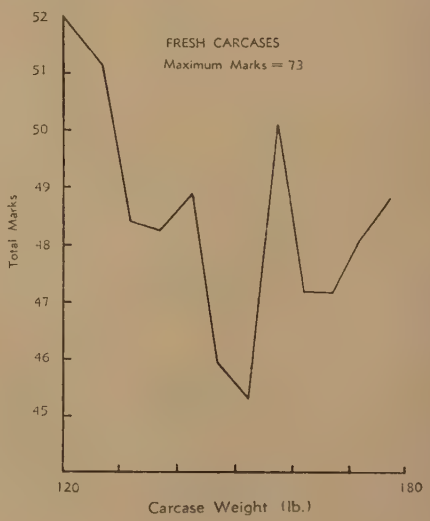


Fig. 6.

Relationship of Total Marks to Weight—Fresh Carcases.

CONCLUSIONS.

Table 12 sets out the regression coefficients that have been calculated for the various measured characters and the significance of differences from the Hammond standard. Since the difference is considerable in some cases, and is sufficient to affect certain carcase weight ranges, an assessment was made to determine if any overall bias sufficient to affect competition results for measured characters exists.

It can be seen from Figures 5 and 6 that, though there may be a slight tendency for the system to favour the lighter carcase, this is not significant in either the cured or the fresh carcase classes.

The following general conclusions are drawn from the study:—

1. Analysis of observations made on the measured characters of body length, eye muscle thickness and leg length reveal the existence of biases favouring certain weight ranges when the Hammond standards are used under Queensland conditions. There was no apparent difference between observed values and the Hammond ideal for backfat thickness.

2. There was no significant overall bias apparent when total marks were considered against weight range. This suggests either that the individual biases have a cancelling effect or that the sampling error was too large to reveal any significant trend.

3. The weight distribution of the carcases submitted lends support to the view that the application of Hammond's table of marks for weight range suitability is not warranted under pig carcase competition conditions in Queensland.

4. Under-finished and overfat types were encountered in equal numbers.

ACKNOWLEDGMENTS.

Mr. P. B. McGovern, M.A., B.Sc. (Biometrician in the Division of Plant Industry) gave valuable advice and assistance and officers of the Pig Branch made helpful suggestions.

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ON METHODS FOR THE ISOLATION OF SALMONELLA FROM CHICKENS.

By G. S. COTTEW, B.Sc., Assistant Bacteriologist, Division of Animal Industry.

SUMMARY.

The efficiency of some selective media for isolating Salmonella from chickens was investigated.

From each of 268 birds the liver, lung and intestinal mucosa and contents were cultured. These were sown on to direct plates of MacConkey, bismuth sulphite and S.S. agar and into tetrathionate broth.

S. pullorum was recovered most frequently from the lung, while most isolations of other species of Salmonella were made from the intestine.

An efficient yet economical method for routine isolations of Salmonella from chickens was adopted.

INTRODUCTION.

One of the common causes of mortality in young chickens in Queensland is Salmonella infection. As no consistent lesions are found, post-mortem diagnosis of these infections rests upon the isolation of Salmonella from the chickens.

The incidence of these diseases is highest in chickens under three weeks of age, so all such birds submitted to the Animal Health Station for diagnosis are examined bacteriologically. Older chickens are cultured at the discretion of the pathologist. These routine examinations require a method of culturing which will produce the maximum recovery of Salmonella organisms consistent with economy of time and media. It was therefore decided to determine the efficiency of various selective media and combinations of media for the isolation of Salmonella, particularly *Salmonella pullorum*. Previous experience at the Station, together with reports by Mallmann, Ryff and Matthews (1942) and Bushnell and Porter (1945), indicated that, of the available media, some combinations of MacConkey, S.S., and bismuth sulphite agar in conjunction with tetrathionate broth enrichment would be suitable media for trial.

MATERIALS AND METHODS.

The bismuth sulphite, S.S. and Kligler iron agar used were Difco products.

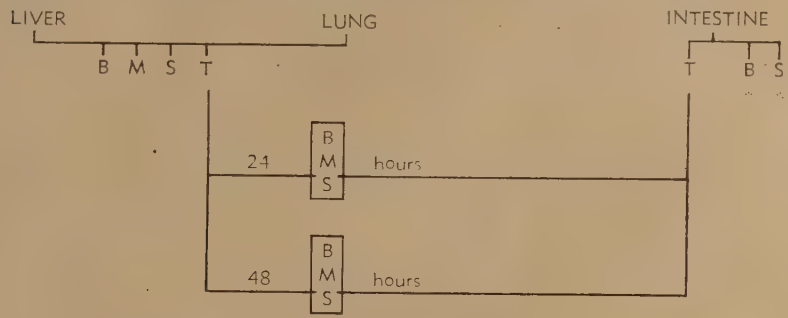
MacConkey agar was made up using the Difco (1948) formula but substituting 17 gm. agar per litre for the 13 gm. specified.

Tetrathionate broth was made to the formula of Mackie and McCartney (1948). Before use, 0·2 ml. of iodine solution was added to 10 ml. of base. This solution was prepared by grinding together in a mortar 6 gm. of iodine and 5 gm. of potassium iodide, then dissolving the mixture in 20 ml. distilled water.

Urea agar was made according to the method of Christensen (1946).

Sick chickens were submitted by officers of the Poultry Branch, Department of Agriculture and Stock, or by the owners. When four or more birds were presented, four only were cultured. When less than four birds were submitted, all of them were cultured. Sick birds were used where possible in preference to dead ones to reduce the number of contaminating organisms.

From each bird one lobe of the liver was detached with sterile forceps and the cut surface smeared on portion of half plates of MacConkey, S.S., and bismuth sulphite agar. The forceps were flamed thoroughly. One lung was then removed and smeared on portion of the other half of these plates. The smeared portion served as a primary inoculum and was stroked out with a sterile wire loop. The intestine was removed and laid on clean paper, then opened lengthwise with sterile scissors to expose the contents. A representative sample of the contents and of the mucosa was collected by scraping with a sterile nickel spatula. This was sown on S.S. and bismuth sulphite agar whole plates, and into tetrathionate broth. The plates were stroked out, incubated for 24 hours at 37°C. and examined. Tetrathionate broths were incubated at 37°C. and were plated on to half plates of MacConkey, S.S., and bismuth sulphite agar after 24 hours' and again after 48 hours' incubation. All plates containing no Salmonella-like colonies were incubated for a further 24 hours at 37°C. The method can be represented schematically thus:—



B = Bismuth sulphite agar; S = S.S. agar;
M = MacConkey agar; T = Tetrathionate broth.

* Here the inoculum was spread on the whole plate. Two inocula were spread separately on each of the other plates.

It will be seen that 11 plates and two tetrathionate broths were used for each bird.

Colonies fermenting lactose on MacConkey or S.S. agar were not identified.

Several suspicious colonies from each plate were sown onto Kligler iron agar and urea agar slopes, which were incubated at 37°C. overnight. Urea positive slopes indicative of Proteus were discarded.

Slide agglutinations with the growth produced on the Kligler or urea agar slopes were done with polyvalent "O" Salmonella serum. Positives were

grouped with Group A, B, C, D, E sera. Suspicious colonies were also sown in nutrient broth to inoculate 1-0 per cent. carbohydrate media (glucose, sucrose, maltose, mannite, lactose) and tryptone water (for the indole test). Generally one set of "sugars" was used for each organ cultured. When more than one serological group was found on a plate, a colony of each group was sown into nutrient broth. The broths were incubated for 5-6 hours and each was used to inoculate a set of "sugars."

One culture per bird of every serological group found was sent to Miss N. Atkinson at the Institute of Medical and Veterinary Science, Adelaide, for specific serological identification.

RESULTS.

Eighty batches containing a total of 268 chickens were examined.

Table 1 shows the isolations of Salmonella on each medium from each source for the 44 birds which were infected with one or more types of Salmonella. From 14 chickens, *S. pullorum* was isolated. Other Salmonella were isolated from 32 birds.

Table 1.

THE DISTRIBUTION OF RECOVERIES OF SALMONELLA.

Number of Bird.	Direct Plates.		Tetrathionate. Liver and Lung.		Direct Plates. Intestine.	Tetrathionate. Intestine.	
	Liver.	Lung.	24 Hours.	48 Hours.		24 Hours.	48 Hours.
	M S B	M S B	M S B	M S B	B S	M S B	M S B
1						S	S S
2	P P P	P P P	P P	P P P		P P P	P P P
3		P P P	P P	P P P	P P	P P	P P P
4						S S S	S S S
5		S				S S	S S S
6	S S S	S S S	S S	S S			
7	S S S	S S	S S	S S S	S	S S	S S S
8						S S S	S S S
9			S S S	S S S		S S S	S S S
10	S		S S S	S S S			S S
11							S
12	P P P	P P P	P P		P P	S S	S S S
13	P P	P P P	P P		P	S S S	S
14	P P P	P P P	P P P	P P P	P P	P P P	P P P
15		P P		P P P	P		
16		P P P	P P	P P P	P		
17					P		
18		S S	S S S	S S S		S	S S S
19		S					

Table 1—continued.

THE DISTRIBUTION OF RECOVERIES OF SALMONELLA.

Number of Bird.	Direct Plates.		Tetrathionate. Liver and Lung.		Direct Plates. Intestine.	Tetrathionate. Intestine.	
	Liver.	Lung.	24 Hours.	48 Hours.		24 Hours.	48 Hours.
	M S B	M S B	M S B	M S B	B S	M S B	M S B
20	S		S S	S S S	S S	S S S	S S S
21	S S	S S	S S S	S S S	S S	S S S	S S S
22	S		S S S	S S S	S	S S S	S S
23	S		S S	S S S	S S	S S S	S S S
24		P P P	P P P	P P P			
25	P P P	P P P	P P P	P P P	P		
26	P P P	P P P	P P P	P P P			
27	P P P	P P P	P P P	P P P	P P	P P P	
28			S S S	S S S		S S S	S S S
29							S S S
30			S S	S		S S	S S S
31			S S S	S S S		S	S
32						S S	
33							S S S
34			S S	S S	S S	S S S	S S S
35						S S S	S S S
36						S S S	S S S
37						S S S	S S S
38					S	S S S	S S S
39	S S		S S S	S S S		S S S	S S S
40				S S S			S
41	P P P	P P P	P P P	P P P	P		
42	P P P	P P P	P P P	P P P	P P	P P P	P P P
43	S		S S	S S S		S S	S S S
44	S	S	S S	S S S		S S	S S S
S. pullorum ..	8 9 9	13 13 12	9 11 11	11 11 11	9 7	4 5 5	4 4 4
Other Salmonella	6 6 4	4 5 3	16 15 9	16 16 15	5 6	20 23 19	23 27 26
Total ..	14 15 13	17 18 15	26 26 20	27 27 26	14 13	24 28 24	27 31 30

The horizontal lines separate birds from different batches.

P = S. pullorum. M = MacConkey agar.

S = Salmonella other than S. pullorum. S = S.S. agar.

Blank = No Salmonella isolated. B = Bismuth Sulphite agar.

S. pullorum.

One of the 14 isolations of *S. pullorum* was made on only one of the 20 possible platings* used on the bird. This was on the direct plating of intestine on S.S. agar (Table 1, Chicken No. 17).

The other 13 isolations were made from varying combinations of the three sources† (liver, lung, and intestine). The lung was one of the sources in each case.

From the direct plating of the lung, the organism was recovered on both MacConkey and S.S. agar 13 times, and on the bismuth sulphite agar 12 times.

The liver sown on direct plates yielded fewer isolations.

Tetrathionate broth sown with pooled lung and liver was instrumental in recovering a large proportion of the *S. pullorum* isolated. From platings of this broth after 24 hours' incubation, the organism appeared somewhat erratically on the three solid media. However, after 48 hours' incubation and subsequent plating of the tetrathionate broth, *S. pullorum* grew in each of 11 cases on all three solid media.

Isolations from the intestine, either on direct plates or after tetrathionate enrichment, were few in number.

Other Salmonella.

Thirty-two isolations of Salmonella other than *S. pullorum* were made.

Isolations from direct plating of the three sources were few, the maximum for any one plating being six.

Tetrathionate enrichment yielded many more isolations. Again the platings of the tetrathionate incubated for 48 hours showed a slight increase in the number of recoveries over the platings made at 24 hours. The solid media did not differ significantly in the number of recoveries from these tetrathionate platings.

The apparently anomalous total of 46 isolations (Table 2) is due to the presence of *S. pullorum* together with other Salmonella in two birds (*see* Table 1).

These birds were from a flock infected with three species—*S. pullorum*, *S. worthington* and *S. meleagridis*. Two chickens (13, 18) from this flock yielded two of these species, while another chicken (13) yielded all three species. On several plates from these birds two different serological groups were represented, indicating the need for slide agglutinations to be carried out with several colonies on each plating.

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* The word "plating" is used to denote the sowing of material on a solid medium whether only half the plate or the whole plate was used.

† The word "source" is used to refer to the materials examined—namely, liver, lung, and intestinal contents.

Direct and Indirect Plating.

In Table 2, the number of isolations which would have been made if the direct plates only had been used is compared with the number of isolations resulting from the use of only the tetrathionate platings.

Table 2.

COMPARISON OF TOTAL ISOLATIONS MADE BY DIRECT AND INDIRECT METHODS.

Organism.	Number of Isolations.		
	Direct Plates only.	Tetrathionate Platings only.	Total (Direct + Tetrathionate).
S. pullorum	14	13	14
Other Salmonella ..	15	31	32
All Salmonella	29	44	46

DISCUSSION.

The lung appeared to be a favourable site for the isolation of *S. pullorum*, while the intestine was a poor source. For species of Salmonella other than *S. pullorum*, the intestine appeared to be the best source.

Comparison of direct and indirect plating emphasises the importance of preliminary enrichment in tetrathionate (Table 2). With Salmonella other than *S. pullorum*, tetrathionate enrichment was responsible for over twice the number of isolations that direct plates produced. With *S. pullorum*, direct plating was very effective, particularly in the case of the lung. Tetrathionate enrichment was almost equal in value. The results were examined with a view to devising an efficient method for isolating Salmonella which would be economical in the use of time and media.

Tetrathionate broth enrichment was responsible for the isolation of 44 strains of Salmonella, whereas direct plates were responsible for only 29 strains being isolated. The combination of media used in this experiment resulted in a total of 46 strains. The two strains which the tetrathionates did not detect occurred on direct plates, but in both cases on one plate only (Nos. 17, 19). Apparently the organisms were present in very small numbers. In addition, each strain was isolated from the least expected source. The *S. pullorum* was found on direct S.S. plates of the intestine and the other Salmonella came from the direct S.S. plate of lung. Although it is tempting from the viewpoint of economy to reduce the amount of media drastically and use only tetrathionate platings. the odd Salmonella may be missed. To reduce this apparently slight possibility, it was decided to include a direct plate. Supporting this move is the fact that should Salmonella grow on the direct plate, one day is saved in establishing a diagnosis. This is of importance in routine laboratory work. The direct plate which seemed to be most effective was the S.S. plate of liver and lung.

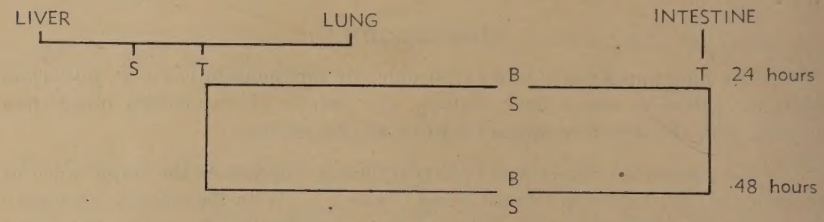
Examination of Table 1 revealed that plating of tetrathionates on MacConkey was unnecessary. The same results would have been obtained had this medium not been used. The method of culturing decided upon was as follows:—

From each bird the liver and lung were sown directly each on to half of an S.S. agar plate. These organs were pooled in a tetrathionate broth. The intestinal contents were placed in a second tetrathionate broth. After 24 hours' incubation, each of these broths was plated on to half an S.S. and half a bismuth sulphite agar plate. This was repeated after the broths had incubated for 48 hours.

The media used for each bird were therefore two tetrathionate broths, two bismuth sulphite agar plates and three S.S. agar plates.

This method would have achieved 45 of the 46 isolations made during the experiment.

The method may be represented schematically thus:—



B = Bismuth sulphite agar.
S = S.S. agar.
T = Tetrathionate broth.

Both bismuth sulphite and S.S. agar would still have to be used for plating tetrathionate broths, as on several occasions one of them failed to grow the organism. On each of these media Salmonella colonies were readily distinguished from all organisms except Proteus. The urea agar slope provided an efficient method of demonstrating the presence of this organism.

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